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THE LAW OF EVOLUTION AS A MAXIMAL PRINCIPLE

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UNDOUBTEDLY fundamental to the concept of evolution is the idea that it is in some significant sense a *directed* process. As soon, however, as we seek to define in precise terms its presumably characteristic direction we meet with difficulties. To say, as some have said or implied, that the direction of evolution is the direction of progress, is merely to substitute for an undefined term another at best ill defined,[1] and contaminated with anthropomorphic flavor. Such phrases as "passage from lower to higher forms" which are sometimes used to describe the direction of evolution, are open to the same objection. If, on the other hand, it is stated that evolution proceeds from simpler to more complex forms, from less specialized to more specialized forms, the direction of evolution is but poorly defined, for the rule is one with disturbing exceptions, and what we seek is not an empirical rule, but a law of nature that brooks no exceptions.

One description of the direction of evolution which has a certain superficial appearance of greater scientific precision is that evolution

[1] B. Petronievics (*Science Progress*, 1919, p. 407) expressly distinguishes *progressive*, *regressive*, and *mixed* evolution. I cite this, not in evidence for, or refutation of, progress as a characteristic of evolution, but merely to show that the term "progress" is itself too indefinite to be used to characterize the direction of evolution.

proceeds from less probable to more probable states. That this appearance of precision is fallacious can be seen from a simple example. In a new pack of cards the first thirteen cards are the Ace to Ten, Knave, Queen, King, of Spades, arranged in that order. If we shuffle the cards thoroughly, we shall presently find the suit of spades distributed approximately evenly throughout the pack. We can express this by saying that in the original arrangement the spades had a density of *one,* or *100 percent,* in the first quarter of the pack, and a density *zero,* in the rest of the pack, whereas at the end of the shuffling they approached much more nearly a uniform density of 13/52 or 25 percent throughout the whole pack. In an actual trial the following distribution was observed after thorough shuffling:

	Spades	
	Number	*Density* (per cent)
First quarter of pack	3	23.1
Second quarter	3	23.1
Third quarter	2	15.4
Fourth quarter	5	38.4

In a certain sense it can here be said that the pack of cards, in the shuffling process, has passed from a less probable to a more probable state. But this is not an objective property of either the pack or the process of shuffling. It is a subjective property of the shuffler, or the observer, who takes a special interest in the suit of spades picked out for observation, and who uses two fundamentally different modes of description for the initial and the final state of the pack: In describing the initial state he tells us specifically what the first 13 cards are; he describes the final state only in terms of a density. There is only one specification that correctly describes the arrangement of the new pack; there are a great many different arrangements that would have the particular density observed in the shuffled pack. If the final state is defined with the same detail as the initial state, namely by indicating each card and its position in the pack, then the final state is just as probable or improbable as the initial state. In the shuffling of the cards the passage is not from a less probable to a more probable state, but from a precisely known to a less well known state. The distinction is not objective but psychological. The future is here known only statis-

tically because we deliberately shuffle in such manner as to have only statistical knowledge of the course of events.

Evidently, then, the statement that evolution proceeds from less probable to more probable states is, not so much a false statement, as it is a statement devoid of meaning, unless it is further supplemented by a specification as to how and in what respects the probabilities of these states are measured.[2]

The example of the card shuffling is also suited to illustrate another point. It has been remarked by various writers[3] (including the present),[4] that evolution is an *irreversible* process: Now the term *irreversible process* has acquired a very special meaning in the vocabulary of the physicist, and not every process that might be described in ordinary speech as irreversible falls into the category of irreversible processes as the physicist understands the term. The suffling of the pack of cards is an irreversible process in the sense that never *by mere shuffling* could the initial state of the pack be restored. The cards would be worn to rags before the spades ever appeared in order at the top of the pack.

But note that, except for the peculiar psychological effect which the marks on the cards have upon certain human minds, the 52 cards of the pack are physically as good as identical. Except again as through their peculiar action on human minds, the particular order of the cards is practically without effect upon the course of physical events. Such shuffling as this is physically in the same category as the interdiffusion of two quantities of the same gas when intercommunication is established between the two vessels containing them at the same temperature and pressure. This is not the type of process which the physicist terms irreversible; it is thermodynamically indifferent. An irreversible pro-

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[2] The significance of the particular kind of passage from less probable to more probable states which plays a role in statistical mechanics arises from its connection with certain energy relations, namely from the fact that processes so characterized can be made to yield a balance of work. The shuffling of a pack of cards is devoid of this characteristic.

[3] In particular, L. Dollo. See B. Petronievics, Sur la loi de l'évolution irréversible, *Science Progress*, 1919, p. 406. See also pp. 418-419 for bibliography.

[4] A. J. Lotka, *Elements of Physical Biology*, 1925, pp. 23 *et seq.* But the concept of irreversibility is there introduced mainly to distinguish an evolutionary process from a purely periodic process and to characterize the forward direction in time.

cess, as the physicist uses the words, is associated with decrease in thermodynamic potential, with capacity for yielding a balance of work, as when one gas diffuses into *another* gas. By a purely physical device (semipermeable membrane or porous partition) such diffusion can be made to operate, for example, a pointer moving over a graduated dial, to warn of the presence of an explosive gas mixture.

Now it may be objected that the shuffling of the pack of cards, though it cannot affect the course of events through the action of any *simple* physical device, could indeed be made to do so by the aid of a sufficiently intricate "purely physical" contrivance, such as an electric eye (as distinguished from psychological interference). This is true, but the fact is itself instructive. For there is an important difference between the operation of the danger signal pointer under the influence of gaseous diffusion, for example, and the automatic door opener actuated by the aid of an electric eye: The energy for the operation of the former is furnished by the diffusing gas itself, whereas the electric eye acts merely as the "trigger" or "key" to release energy supplied by a separate source. In this it truly copies the human eye, and indeed all our sense organs, the role of which, in their part in human behavior, is typically to act as "triggers,"[5] operated, as a rule, by the application of a very small dose[6] of external energy, the "stimulus," to set in action a wholly disproportionate amount of energy drawn from the total sources available in the living body, or, by secondary trigger action, from still more abundant sources outside the body. These are cases of "relay" action, of which probably the most advanced example, in contrivances of human construction, is the amplifier of a radio set.

The fact is, in the last analysis irreversibility is a relative thing, and is due to restrictions placed naturally (by physical or economic

[5] The significance of trigger action seems to be have been first pointed out by N. L. S. Carnot, and more specifically by Barré de Saint Venant, who speaks of it as *travail de décrochement,* as in the pulling of a *déclic* (trigger). See Boussinesq, *Cours de physique mathématique,* Tome III, p. XXXII (in section "Conciliation du véritable déterminisme avec l'existence de la vie et de la liberté morale"). Paris, Gauthier-Villars, 1922, but referring to original publications in 1872, 1878.

[6] According to S. Hecht, under the most favorable conditions, the smallest amount of light which the human eye can detect is 58-148 quanta, representing an energy of $2\text{-}6 \times 10^{-10}$ ergs. Actually only about one-tenth of this is absorbed by the retina; the rest is lost by corneal reflection, absorption by ocular media and passing on beyond the retina. (Abstract in *Nature,* July 1, 1944, p. 13)

constraints) or arbitrarily upon operations permitted. Just as the trisection of an angle is or is not an impossible feat, according as we prohibit or allow the use of instruments other than straight edge and compass, so a process may be described as irreversible or not, according as we are restricted (by physical or economic constraints) to operations in bulk, or are allowed to operate separately upon individual elements.

While these facts bear an important relation to the central problem of organic evolution, the vagueness of the concept of irreversibility in its broader interpretation demands very special caution in its application to the general problem of evolution. It is quite true that a species of irreversibility very like that contemplated in thermodynamics, as applied to processes on a molecular scale, plays an important role also in large scale processes, in which our faculty of "sorting," or "unshuffling," i. e. reversing the spontaneous "mixing" processes of nature, gives us a material advantage. But merely to state that "a biological species never retraces its steps," or that "when a race has lived its term it comes no more again," does not characterize an "irreversible" process in any useful sense, for this does not distinguish the chain of events from a mere "changeful sequence." If the world's events taken in historical order *A, B, C, . . .* are a changeful sequence, the same would be true of the inverted sequence *. . . C, B, A.* This kind of "principle of irreversibility" has no prognostic value. It tells us at best that if the sequence *A, B, C* happens, then the sequence *C, B, A* will not happen, and vice versa; but it does not tell us which of the two actually will happen. *After* the event it calls the one that *has* happened "irreversible."[7]

Another characterization of the direction of evolution that has been given is that it is the direction of increasing organization. Those who have in the past propounded this view have not told us how to measure organization, as would be necessary in order either to establish or to refute such characterization.[8] But assuming that an appropriate measure were forthcoming, this could at best lead to an empirical ob-

[7] "Dollo's Law of Irreversibility, even in its modern phrasing: Evolution is reversible in that structures or functions once gained may be lost, but irreversible in that structures once lost can never be regained," is not borne out by facts. A. J. E. Cave and R. Wheeler Haines, *Nature*, Nov. 4, 1944, p. 579.

[8] C. C. Lienau has presented an interesting suggestion for the mathematical treatment of this problem. But this applies to special cases. It does not enable us, for example, to appraise quantitatively, and to compare with each other, as to degree of organization, the elephant, the frog, the housefly, the oyster or amoeba.

servation that evolution in a large number of cases has proceeded along the line of increasing organization. While such studies have a definite interest, they belong in the domain of descriptive science. What we seek is a deductive scheme in which the law of evolution is seen to flow as a *necessary* consequence from fundamental laws, as a result of the physical properties of the organisms and the system of which they form part.

The standards of the exact sciences look beyond mere description. They aim at establishing coherent disciplines within which, by the application of relatively few fundamental principles, the course of events can be rigorously *deduced* for innumerable specific situations. So, for example, an application of the first and second laws of thermodynamics (the laws of conservation and of dissipation of energy) to a system composed of *any* liquid and its saturated vapor enables us to deduce the latent heat of vaporization of the liquid if three characteristic properties of the substance are known, namely its specific volume in the liquid and vapor form, and the temperature coefficient of its vapor pressure.

The phenomenon of increasing organization, which in a somewhat loose qualitative sense may be admitted to be a common characteristic of organic evolution, is far too complicated and too inexactly defined[9] a conception to be classed with such basic principles as the two laws of thermodynamics, for example. It is rather the sort of thing that we might hope to derive as a consequence of the properties of living organisms and some other more basic principle or principles.

To accept a "law" of increasing organization as a basic principle would be to shut the door to further important analysis by prematurely pronouncing as solved a problem that actually is hardly even approached: to establish the fundamental law governing the course of evolution in a system composed of aggregations of energy transformers of a

[9] To speak vaguely of increasing organization, without indicating any method of measuring, is merely another way of stating the obvious fact that certain of the most successful competitors owe their success to adaptation enabling them to deal with a greater and greater variety and diversity of circumstances. This is achieved by the acquisition of certain structures performing certain functions—that is, by organization. But this is only *one* direction in which evolution may proceed. While certain species have thus moved in the direction of greater and greater capacity for individual survival under varied conditions, others have assured race survival by great fertility of the species in the face of a lower degree of adaptation of the individual. These two types survive together, the one, in many cases, depending on the other for food. A shining example of this bilateral adaptation is man and certain domestic animals kept for slaughter.

peculiar type, competing for the substances and energies requisite for their continued existence and operation. In this search we are looking, not for a new *empirical* formulation, but for *necessary* relations deduced from known universal principles.

From a purely formal[10] statement in mathematical symbols of the fact that in general the rate of growth of each organic species is "some function" of the amounts of coexisting species, it is possible, on rather broad assumptions, to set up a function (or, indeed, a whole class of functions) of the amounts (masses) of the several species, which has the property of approaching a maximum or a minimum as the several coexisting species proceed toward a stable adjustment. Such purely formal expressions have been indicated by Lotka,[11] and in greater detail and perfection by Volterra.[12] The latter author names the function thus established by him the "demographic potential" of the system. This use of the term "potential" cannot be commended. Potential is a

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[10] Such a purely formal statement does not necessarily have any deeper significance. *Cf.* G. D. Birkhoff, "One can manage to obtain a variational principle appropriate to almost any physical or mathematical theory," *Scientific Monthly*, 1944, vol. 58, p. 54.

[11] A. J. Lotka, Evolution and Irreversibility, *Science Progress*, 1920, vol. 14, pp. 406, 412.

[12] V. Volterra, Principes de biologie mathématique, *Acta Biotheoretica*, 1937, vol. 3, part 1. See especially pp. 18, 20, 30, where also the terms *énergie démographique* and *principe de moindre action en biologie* are used in a sense not conforming with their strict usage in physics. Other authors who have employed the term "potential" in similarly loose fashion are R. N. Chapman, *Animal Ecology*, 1926, p. 145, and L. Hersch, *Publications des sciences économiques et sociales de l'Université de Genève*, 1944, p. 64.

Another loose transference of a verbalism from the domain of physics to that of biological phenomena, made without adequate critical examination of the underlying assumptions and the conditions for its validity, is the tentative application of the *Principle of Le Chatelier* by various authors (e. g., O. D. Chwolson, F. Le Dantec, W. D. Bancroft). How incautious such applications are can be seen from the fact that even in the domain of physical systems, where conditions are much simpler and more clearly defined, erroneous applications have been common, as pointed out by P. Ehrenfest (*Zeitschr. f. phys. Chemic.*, 1911, p. 735). An analysis of the conditions for the valid application of the principle cannot be entered into within the scope of this article. For such the reader must be referred to my *Principles of Physical Biology* (1925), Chapter XXII, Displacement of Equilibrium, especially pp. 281 *et seq.*, and the references there cited, in particular, A. J. Lotka, The General Conditions for the Validity of the Principle of Le Chatelier, *Proc. Amer. Acad. Arts and Sciences*, 1922, vol. 27, p. 21; The Principle of Le Chatelier in Biology and Medicine, *Am. Jl. of Hygiene*, 1923, vol. 3, p. 355.

technical term in physics, of the dimensions of an energy, and Volterra's analysis nowhere introduces considerations of energy or of the peculiar mechanical properties of the organism. If we were dealing in problems wholly unconnected with energetics, the borrowing of a term from that field in a purely figurative sense might be condoned. But, quite on the contrary, the energy relations of the system of organic nature are a deeply fundamental feature, in which potentials of some kind, in the physicist's meaning, may be expected to play a role. To christen a function as a potential, which does not have the dimensions and qualities of a potential in the physicist's meaning, is to create the impression that a problem has been solved which, actually, still awaits solution. This does not make for the advancement of science.

A better signpost to point us in the right direction is given in Bertrand Russell's *An Outline of Philosophy*:[13]

> Every living thing is a sort of imperialist, seeking to transform as much as possible of its environment into itself and its seed . . . . We may regard the whole of evolution as flowing from this 'chemical imperialism' of living matter. Of this man is the last example (so far). He transforms the surface of the globe by irrigation, mining, quarrying, making canals and railways, breeding certain animals and destroying others; and when we ask ourselves, from the standpoint of an outside observer, what is the end achieved by all these activities, we find that it can be summed up into one very simple formula: to transform as much as possible of the earth's surface into human bodies . . . . And in pursuing the simple purpose of maximizing the amount of human life, we have at any rate the consolation of feeling at one with the whole movement of living things from their earliest origin on this planet.

Now a good signpost points the way, but it also tells us that we have not yet arrived. If each species seeks to maximize its own mass, what is the over-all result? It is, of course, conceivable that ultimately one single species (perhaps man) might dominate the scene to the exclusion of all others. But short of this eventuality, or at any rate until it is attained, the problem is one of distribution. What determines the distribution of the total matter of the system among the several species and individual organisms, and the successive changes in this distribution? Is there some significant physical quantity which these competing organisms maximize by their collective activities?

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[13] Bertrand Russell, *An Outline of Philosophy*, London, 1927, p. 27.

Problems of distribution are not new to the physical sciences. The whole topic of *Change of State* deals with precisely such problems: The distribution of a mass of water between the liquid and the vapor phase, or between the solid and the liquid phase, under specified conditions of volume, temperature, etc.; the distribution of hydrogen and oxygen between the three components of a system composed of these substances in elementary form, H_2 and O_2 on the one hand, and in combination as water, H_2O, on the other, again under specified conditions, etc. As applied to these cases the law of evolution is well known and clearly defined. It states that for an isolated system, for example, the entropy of the system increases to a maximum as the system approaches equilibrium; or, more generally, that certain clearly defined functions of the parameters specifying the state of the system—its thermodynamic potentials—approach a minimum.

A special example which has often been cited, because of a certain superficial analogy to the growth of a colony of bacteria in a suitable nutrient medium, is that of the crystallization from a supersaturated solution, upon the introduction of a crystal "germ" of the dissolved substance. So long as the supersaturated solution is left undisturbed it may remain as such for long, perhaps indefinite periods, though seemingly spontaneous crystallization may also take place. This restricted type of stability has sometimes been spoken of as the *metastable* state. Its thermodynamic potential is not at the minimum possible for the system, and hence, as soon as an available "path" is presented (by the introduction of the crystal germ), the transformation to the crystal form is initiated. It continues until that particular amount of the solid has formed which is required to bring about *stable* equilibrium, that is, to make the thermodynamic potential a minimum.

If this were merely outward appearance of analogy, the oft repeated example would hardly be worth quoting again here. But it is literally true that the nutrient solution is "metastable" in the absence of a germ of an organism capable of growth in it. Whether in primordial nature somewhere locally such a state presented itself, and whether the metastable state could pass over into some kind of elementary "living" matter without the presence of a preexisting germ, just as crystallization of a supersaturated solution can take place even in the absence of a

crystal germ, that is today still one of the unsolved problems of science.[14] But if such was the origin of life, we know that it was followed by a long chain of evolutionary development. And just as the continued growth of the crystal, from the first germ to the completely formed solid phase, is governed by the law that this process proceeds with continuous diminution of thermodynamic potential of the system solution plus crystal, so we may expect that the law of organic evolution takes the form that it is accompanied in the long run with diminution of some function, analogous to thermodynamic potential, of the parameters defining the physical state of the system as a whole.

While the problem of organic evolution, as a problem in the distribution of matter among the components of a material system, is formally in the same general category as these problems of distribution in physico-chemical systems, it differs, of course, in certain important respects from the specific problems considered in physico-chemical dynamics and statics. What are actually the significant points of difference?

First, that the ultimate individual components recognized in physico-chemical transformation—molecules and atoms—escape direct observation by any of the ordinary methods. It is the bulk properties and effects, such as volume, pressure, temperature, etc., of the massive components, which are directly accessible to observation, and in terms of which thermodynamics receives its data and states its conclusions. The investigation of the detailed actions of individual molecules and atoms requires altogether different, highly refined techniques.

The establishment of the statistical relations between the individual actions and the bulk effects is an additional discipline of great interest—statistical mechanics—but is not primarily necessary for the knowledge of the bulk effects, since they are directly observed with greater ease than the individual actions.

Diametrically opposite is the situation when we study organic evolution. Here it is the individuals, the separate organisms, that are accessible to direct observation, while the collective or bulk effects of aggregates of organisms, *as a whole,* (in terms of which we must ex-

[14] This observation, casually introduced by Ostwald in one of his lectures in 1902, was the "trigger" that set off the train of thought developed in my subsequent publications, and summarized, in part, in my *Elements of Physical Biology* (1925) and *Théorie Analytique des Associations Biologiques* (1934, 1939).

pect the law of organic evolution to be primarily expressed) will necessitate the development of a special branch of statistical dynamics.

Secondly, physico-chemical transformations, in all their variety, are nevertheless limited by certain narrow restrictions which hold *for all time*. These transformations run, as it were, along a single track. So for example in the case already cited, in a system composed of specified amounts of hydrogen and oxygen, the relative amounts of H_2, O_2 and H_2O may undergo a progressive change (toward an equilibrium if external conditions are constant), but they will never give rise to hydrochloric acid, for example. This may be expressed by saying that ordinary physico-chemical transformations (exclusive of transmutations of elements) are bound by certain equations of constraint (the "reactions equations") which are fixed for all time.

The transformations between and within organic species are of a different order, because they are in the main transformations of *structure*, which is capable of infinite variation. It is true that here also there are equations of constraint. An eagle is not hatched from a duck's egg. But a white duck may have parti-colored ducklings. Again, it is not possible at the present epoch of the world's history for grass or hay to be converted into mammoth. But some tens or hundreds of thousands of years ago this transformation, or something very much like it, was not only possible, it was a daily occurrence. Thus the equations of constraint that delimit the possible transformations of organic evolution are not only more liberal than those of physico-chemical evolution, they are distinguished by the fact that they are functions of the time, whereas the physico-chemical equations of constraint (e. g. the "reaction equations" of chemistry) are rigidly fixed for all time.

One consequence of this distinctive character of the equations of constraint in organic evolution is that the process is one that never ends, since structure is capable of infinite variation. In contrast to this, a reaction such as that already cited between hydrogen and oxygen proceeds (under given condition) to an equilibrium, often reached within a short space of time.[15]

The fact that the equations of constraint in organic evolution are functions of the time is closely related to a third characteristic. Whereas the components of the systems considered in physico-chemical

[15] That is, for all practical purposes. Theoretically the end state may never be fully reached, but only approached to within a negligible distance.

dynamics—elements, compounds, "phases"—are strictly homogeneous, the component biological species in the system of nature are only *relatively* homogeneous. In comparison with the discontinuous gaps that separate different species, the variations within each species, describable in terms of frequency distributions of characteristics among its individuals, are either practically continuous, or, if discontinuous, proceed by steps much less extreme than those that separate the several species.

In accordance with this, analytic formulation distinguishes two aspects of organic evolution: changes in the distribution of matter among the different species—*inter-species* evolution; and changes in the distribution of the individuals within each species, as defined by suitable frequency functions of their characteristics—*intra-species* evolution.

It is the changing character of organic species that imparts to the equations of constraint their dependence on time. This feature has no counterpart in physico-chemical evolution, since there the components are homogeneous and invariable and present no opportunity for intra-species evolution. On the contrary, in the system of organic nature, intra-species evolution has so prominently engaged the attention of biologists, that attempts to indicate the direction of evolution have commonly been couched with reference to individual species. Actually, as already hinted, any adequate treatment of the problem must envisage the evolving system as a whole—the aggregate of coexisting species and their inorganic environment.[16] Anyone accustomed to the discipline of physico-chemical dynamics knows that it would be quite out of the question to formulate the law of evolution of the system by reference to one of the components alone. The law of organic evolution, likewise, must undoubtedly be formulated in terms of the system as a whole evolving under the flood of light received from the sun.

And this brings us to the fourth typical difference that distinguishes organic evolution from most of the physico-chemical transformations usually considered (adiabatic or isothermal reactions), namely that the latter are envisaged as taking place under conditions leading to an *equilibrium*. Absolutely fundamental to organic evolution is that it takes its course in a system exposed to a continuous stream of energy from the sun, so that the approach is not towards equilibrium, but to-

[16] For a particularly illuminating survey of the planetary relations involved, see W. Vernadsky, *La Géochimie*, Paris (Alcan), 1924.

wards a *stationary state* maintained with continuous expenditure of free energy.[17]

And directly related to this is the fact to which reference has already been made in passing, namely that trigger action plays an important role in organic evolution. For trigger action presupposes a fund of free energy ready to be released, and, as was pointed out years ago by Boltzmann, the life struggle is primarily a competition for available energy. What we have before us in organic nature is a system composed of aggregates of energy transformers adapted by their composition and structure to guide available energy into such channels as lead to their maintenance and growth. A special branch of physics needs to be developed, the *statistical dynamics of systems of energy transformers.* In the development of this it will not be necessary or even desirable to deal primarily with specific living organisms, but rather with transformer *types* possessing certain properties characteristic of the physical *modus operandi* of living organisms. The kind of problem then to be studied will be the relation between the distribution of matter in the system on the one hand, and on the other the particular properties and variation in properties of the several types of transformers of which the system is composed. In so far as the system of organic nature is subject to physical law, certain at least of the relations deduced for the systems studied in this branch of physics should be found applicable to the system of organic nature and its evolution, just as that system is, for example, subject to the law of conservation of energy which is usually thought of as applicable primarily to inorganic systems.[18]

Among the transformers which this branch of physics will have to consider, one important class obtains its supply of available energy from sources distributed discontinuously, in separate masses, through the system in which they operate. This necessitates structures or "apparatus" whereby "collisions" or "encounters" between those transformers and their energy sources are rendered probable. The more perfect the functioning of this apparatus, the greater will be the prob-

[17] In this respect it is similar to photochemical reactions, and indeed, it might be regarded as a photochemical reaction on a heroic scale, accompanied by important structural changes. However, in organic evolution, owing to intra-species changes, the state is only *relatively* stationary; it resembles rather what has been (inaccurately) termed a "moving equilibrium."

[18] Though the principle was originally recognized by J. R. Meyer on the basis of physiological observations.

ability of these encounters, and the less the energy expended in proportion to the energy captured in the encounter, so as to yield a net balance of gain.

In the apparatus by which the probability of favorable encounters is ensured or enhanced four typical elements are to be distinguished, as follows:

1. *Receptors.* The action of the transformer must be a function of the position of the sources. But that action is primarily a function of the state of the transformer itself. Hence there must be apparatus to provide that the state of the environment is in some manner "represented" or "depicted" in the transformer. This may be by optical image formation by a lens, as in the human eye or in an automatic door opener operated by a photoelectric cell; but more generally, the process of "depicting"[19] may take a variety of forms. What is characteristic is that the amount of energy involved in the process may be very small.

2. *Free energy.* Associated with the transformer is a *fund of free energy*[20] ready to be released by trigger action, that is, by an expenditure of an amount of energy bearing in general no quantitative relation to the energy released, which can thus be far in excess of the energy applied at the "trigger."

3. *Effectors,* that is, structures by which the energy released by trigger action from the available fund is applied to react upon the environment so as to bring about an encounter with an energy source to be captured, or so as to avoid an encounter in which the transformer itself will be captured or injured, i. e., made more or less inoperative.

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[19] That is, of establishing a one-to-one correspondence between certain features of the environment and certain appropriate features of the transformer. It is no mere accident of language that we speak of this generalized process of "image formation" in ourselves as *information.* By it we are *informed* of conditions in the environment.

In the case of man the primary representation (depiction) of the environment in the individual is further supplemented or elaborated by a faculty or a set of faculties which we may designate as the elaborators. Their most refined product is the scientific world picture.

[20] It can be noted here only in passing that the possession of such a fund of free energy is what gives the opportunity for purposive action and the exhibition of the phenomenon of *will,* that is, action teleologically aimed at future effects. For a discussion of this the reader may be referred to Chapters XXVIII *et seq.* of my *Elements of Physical Biology,* and, for a more recent review, to A. J. Lotka, Evolution and Thermodynamics, *Science and Society,* 1944, vol. 8, p. 161.

For since these transformers possess a fund of free energy they can themselves become objects for capture by competing transformers. The avoidance of capture is made possible by the existence of refuges scattered through the topography over which they operate.

4. *Adjustors.* Lastly, in order that the receptors and effectors may function successfully in ensuring the probability of encounters with energy sources and in warding off unfavorable encounters, the transformer must comprise apparatus by which the action of the effectors upon the environment is suitably adjusted to the "information" supplied by the receptors.

Since it is characteristic of trigger action that the energy released may far exceed the energy spent in working the trigger, while the energy captured may still further exceed the energy expended from the available fund of the transformer, it follows that a transformer or an aggregate of transformers equipped with apparatus of the type described is capable of continued functioning, obtaining sufficient energy from captured sources to defray the energy cost of capturing further sources. In fact, there may be a balance left over for accumulation, which may take the form of growth of the transformer or of the aggregate of transformers.

In this discussion it has been assumed that there exist "discrete" sources available for capture, scattered through the field of operation of the transformers of the type so far considered.

That such sources exist and are continually replenished in nature is due to the existence of another type of energy transformers, which themselves draw their supply of energy and substance from sources continuously distributed in space, namely sunlight on the one hand, and on the other, gaseous or dissolved substances which drift to them spontaneously by diffusion and seepage. These transformers can accordingly remain essentially passive and do not require the "ingenious" apparatus for capturing energy by trigger action. At the same time they lose the benefit of the power actively to avoid unfavorable encounters. They do, of course, possess various passive means of protection, some of which, incidentally, are available also to animals.

Such are the fundamental data with which the statistical dynamics of aggregates of energy transformers will have to deal. Indications of the direction in which the development of this branch of physics

may be expected to move have been given by the writer elsewhere.[21] For our present purpose only certain broad observations will here be made.

While the transformers in nature are "living" animals and plants, it will be desirable to develop the discipline of statistical dynamics of aggregates of transformer irrespective of this fact. The results achieved must then be applicable to the world of organisms in so far as they are energy transformers having the physical properties taken in view in that discipline, just as the law of conservation of energy, is applicable to them.

Dealing with purely physical data affords certain important advantages. We have complete control of the particular properties which we may assign to the transformers under consideration, without raising the question whether such a transformer actually exists or ever has existed. As Karl Pearson has remarked: "In dealing with natural phenomena . . . . the mathematician has to simplify the conditions until they reach the attenuated character which lies within the power of his analysis."

This process can be carried much farther both experimentally and conceptually in purely physical than in biological systems. The relative simplicity and direction of physical laws is in no small measure due to the fact that experimentally we can control conditions so as to isolate the factors essential to our enquiry, from adventitious circumstances in which for the moment we are not interested.[22]

The fact that we ourselves are of the dimensions of the units (transformers) contemplated in this discipline gives us an inside view of

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[21] A. J. Lotka, *Elements of Physical Biology*, pp. 36, 37, and especially Chapters XXIV to XXXIV. Also, Families of Curves of Pursuit and Their Isochrones, *American Mathematical Monthly*, 1928, vol. 35, p. 421; Contribution to the Mathematical Theory of Capture, *Proceedings of the National Academy of Sciences*, 1932, vol. 18, p. 172. See also V. Lalan, *Compt. Rend.*, 1931, vol. 192, p. 468.

[22] The history of Science well illustrates the importance of this simplification for the progress, and especially the early progress, of a science. Thus astronomy was able to make a very early start because nature herself has simplified some of the basic problems by reducing the data practically to mathematical points, the position of stars (and for the naked eye also the planets) in the sky. At the other extreme we have the case of chemistry, one of the last sciences to develop effectively, because no considerable progress could be made until recognition and separation of the fundamental units of chemistry—elements and pure compounds—had been achieved.

the processes under discussion, and thus enables us to select the appropriate ensemble of properties to assign to the conventionalized models of the actual transformers presented to us in nature's organisms. At the same time we shall retain full freedom, in this process of conventionalization, to place the development of the subject on a postulational basis, if we conduct the enquiry solely in terms of physically defined transformers, since we thus avoid carrying on the discussion in terms of "hypothetical animals and plants," to which some biologists might take exception.

An admittedly primitive illustration of the mode of approach to the problem is the case of a "pursuing" transformer of velocity v_1 seeking encounter with a "pursued" transformer of velocity v_2 while the latter flees in a straight line toward a refuge of safety. The pursuer, constantly directed toward the pursued, then follows a so-called "curve of pursuit." Whether capture occurs or not then depends on the relative position of the pursuer and the pursued at the time when first stage of the pursuit, the "stalk," begins (that is, when the pursuer first directs his course toward the pursued); and depends further on the time when the second stage begins, namely when the pursued first reacts by "flight" to the "attack" of the pursuer. The problem thus conventionalized resolves itself into a problem of geometry. Capture certainly occurs, or does not occur, according as a certain circle does or does not fall within a certain ellipse of dimensions depending on the efficiency of the receptor-effector apparatus of the two types of transformers. If the circle and the ellipse intersect, capture occurs for some initial positions and does not occur for others. In this conventionalized case we can, for example, discuss the influence, upon the probability of capture, of variations in the velocities v_1 and v_2 or in the degree of perfection of the receptors, etc. Carrying the model somewhat further, the influence of the density of distribution of refuges in the territory may be discussed.[23]

It may be objected by some that such primitive—not to say naive—conventionalizations of the natural phenomena of pursuit and capture observed among living organisms, are too far removed from any realities to be of any value.

To this the answer is, first, that the case described is used merely as a simple example of the *kind* of procedure to follow, with appropriate

[23] For details the reader is referred to my two papers cited above, on curves of pursuit and on the theory of capture.

refinements and extensions. And second, that it is well to be very cautious in pronouncing useless a conventionalization merely because it is a seeming over-simplification. Such highly attenuated conventionalizations have done excellent service in certain fields.

The Carnot heat engine, with its perfectly conducting and perfectly insulating parts, is a case in point, and so is the use of a "perfect gas"[24] in illustrating the derivation of the second law of thermodynamics by a Carnot cycle. As is well known, the results so derived are of far-reaching consequence and of the widest applicability.

While the future development of such a discipline of statistical dynamics of aggregates of energy transformers should eventually prove of great interest and importance in relation to the problems of organic evolution, certain broad observations with which its result presumably will conform may be stated even now.

It has been remarked[25] that the influence of living organisms is to retard the dissipation of energy. So far as the plant world is concerned this seems essentially true. Green plants act as accumulators storing sunlight which would otherwise shortly be converted into heat at terrestrial temperatures.

But the influence of animals is essentially in the opposite direction, since their activities are conducted with dissipation of energy, catabolism exceeding anabolism.

At first sight there is something perplexing about these two opposing tendencies. But this perplexity exists only so long as we seek to express the drift of organic nature in terms of a retardation or a promo-

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[24] As to this, it is admitted that both logically and for didactic reasons it is preferable to avoid the use of an unreal working substance in this derivation of the efficiency of a reversible heat engine. It is not the ideal way of treating the subject, though it has a certain heuristic and illustrative value. I have noted that some who had so been initiated into the foundations of thermodynamics gained the impression that the use of a "perfect" gas was a necessary point of the argument—whereas just the opposite should have been impressed upon them—that the argument and its conclusions are independent of the working substance, and that therefore, in the interest of simplicity of the mathematical manipulations *it is permissible* to conduct the argument on the basis of a fictitious working substance—the conclusion is independent of the fact that such a particular substance does not exist.

[25] See J. Johnston, *The Mechanism of Life*, 1921, pp. 220, 221, especially the footnote on page 221.

tion of the dissipative process. As soon as we frankly accept the fact that both are going on side by side the perplexity vanishes.

A simile may be helpful in illustrating the situation. Consider a reservoir constructed to collect rainwater. Now let there be two agencies at work, one tending to enlarge the catchment area, the other tending to enlarge the outlet or outlets from the reservoir. In one sense these two influences seem antagonistic, one tends to increase the volume of water in the reservoir, the other tends to decrease it. But in one thing they cooperate: *Together they increase the total flow through the reservoir.*

From this illustration by analogy, let us return to the actual case before us. The argument, as I have presented it elsewhere,[20] runs as follows: As already noted, "it has been pointed out by Boltzmann that the fundamental object of contention in the life struggle, in the evolution of the organic world, is available energy." In accord with this observation is the principle that in the struggle for existence the advantage must go to those organisms whose energy-capturing devices are most efficient in directing available energy into channels favorable for the preservation of the species.

> "The first effect of natural selection thus operating upon competing species will be to give relative preponderance to those most efficient in guiding available energy in the manner indicated. Primarily the *path* of the energy flux through the system will be affected.
>
> "But the species possessing superior energy-capturing and directing devices may accomplish something more than merely to divert to its own advantage energy for which others are competing with it. If sources are presented, capable of supplying available energy in excess of that actually being tapped by the entire system of living organisms, then an opportunity is furnished for suitably constituted organisms to enlarge the total energy flux[21] through the system. *Whenever such organisms arise*, natural selection will operate to preserve and increase them. The result, in this case, is not a mere diversion of the energy flux through the system of organic nature along a new path, but an increase of the total flux through that system.
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> "Again, so long as sources exist, capable of supplying matter of a character suitable for the composition of living organisms, in excess of that actually embodied in the system of organic nature, so long is

[20] A. J. Lotka, Contribution to the Energetics of Evolution, *Proceedings of the National Academy of Sciences*, 1922, vol. 8, p. 147.

[21] The term *energy flux* is here used to denote the available energy absorbed by and dissipated within the system per unit of time.

opportunity furnished for suitably constituted organisms to enlarge the total mass of the system of organic nature. *Whenever such organisms arise,* natural selection will operate to preserve and increase them, provided always there is presented a residue of untapped available energy. The result will be to increase the total mass of the system, and, with this total mass, also the total energy flux through the system, since, other things equal, this energy flux is proportional to the mass of the system.

"Where a limit, either constant or slowly changing,[28] is imposed upon the total mass available for the operation of life processes, the available energy per unit of time placed at the disposal of the organisms for application to their life tasks and contests, may be capable of increase by increasing the rate of turnover of the organic matter through the life cycle. Suppose, as a simple, though rather extreme illustration, that man found means of doubling the rate of growth of crops, and of growing two crops a year instead of one. Then, without changing the average crop actually standing on the fields, the land would be capable of supporting double the present population. If this population were attained, the energy flux through the system composed of the human population and the organisms upon which it is dependent for food, would also be doubled. This result would be attained, not by doubling the mass of the system (for the matter locked up in crops, etc., at a given moment would be, on the average, unchanged) but by increasing the velocity of circulation of mass through the life cycle in the system. Once more it is evident that *whenever a group*[29] *of organisms arises* which is so constituted as to increase the rate of circulation of matter through the system in the manner exemplified, natural selection will operate to preserve and increase such a group, provided always that there is presented a residue of untapped available energy, and, where circumstances require it, also a residue of mass suitable for the composition of living matter.

"To recapitulate: In every instance considered, natural selection will so operate as to increase the total mass of the organic system, to increase the rate of circulation of matter through the system, and to increase the total energy flux through the system, so long as there is presented an unutilized residue of matter and available energy.

"This may be expressed by saying that *natural selection* tends to make the energy flux through the system a maximum, so far as compatible with the constraints to which the system is subject.

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[28] As, for example, if the total mass of the system is capable of accretion, but only at a limited velocity, in which case the phenomenon of a "moving equilibrium" may present itself. Compare Lotka, A. J., *Proc. Nat. Acad. Sci.*, 1921, vol. 7, p. 168.

[29] Owing to the fact that in existing organisms the anabiotic and catabiotic functions are very largely segregated in different types (plants and animals), evolution will here operate upon systems or groups of at least two species, one species of autotrophic anabions, and one of heterotrophic catabions.

"It is not lawful to infer immediately that *evolution* tends thus to make this energy flux a maximum. For in evolution two kinds of influences are at work: selecting influences, and generating influences. The former select, the latter furnish the material for selection.

"If the material furnished for selection is strictly limited, as in the case of a simple chemical reaction, which gives rise to a finite number of products, the range of operation of the selective influences is equally limited.

"In the case of organic evolution the situation is very different. We have no reason to suppose that there is any finite limit to the number of possible types of organisms. In the present state of our knowledge, or rather our ignorance, regarding the generating influences that furnish material for natural selection, for organic evolution, an element of uncertainty enters here. It appears, however, at least *a priori* probable that, among the certainly very large (if not infinite) variety of types presented for selection, sooner or later those will occur which give the opportunity for selection to operate in the direction indicated,[20] namely so as to increase the total mass of the system, the rate of circulation of mass through the system, and the total energy flux through the system. If this condition is satisfied, the law of selection becomes also the law of evolution:

"Evolution, in these circumstances, proceeds in such direction as to make the total energy flux through the system a maximum *compatible with the constraints.*"[21]

As for these constraints, over relatively short periods of time, when we are dealing mainly with inter-species evolution, they are defined essentially by transformation coefficients indicating in what ratio the mass added in the growth of one species stands to the masses captured from other species or from the environment. For, growth in *mass* of organisms takes place by the assimilation of food, though growth in *numbers* takes place by reproduction (births), which thus acts as pacemaker for the growth in mass.

Over extended periods of time, as already noted, the constraints are functions of the time, and the empirical data which define them are sup-

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[20] One is inclined here to give at least qualified assent to the saying of Herodotus: "If one is sufficiently lavish with time, everything possible happens." (Cited by C. E. Guye, *Physicochemical Evolution*, Methuen & Co., London, 1925, p. 30. This is essentially a republication in English of a series of papers originally appearing in various French journals, 1917 to 1920.)

[21] A further analytical development based upon this principle has been suggested by N. Rashevsky, Outline of a New Mathematical Approach to General Biology, II, *Bulletin of Mathematical Biophysics*, 1943, vol. 5, p. 49.

plied mainly—but with one highly significant exception—by the findings of genetics.

The one outstanding exception is the human species. Here evolution, especially in more recent times, has followed an entirely new path. In place of slow adaptation of anatomical structure and physiological function in successive generations by selective survival, increased adaptation has been achieved by the incomparably more rapid development of "artificial" aids to our native receptor-effector apparatus, in a process that might be termed *exosomatic* evolution.[32]

Until recently the net effect of these new implements of evolution has been essentially in the same direction as the main current. Man, one of the latest, and in his own judgment the highest product of evolution, has hitherto signally conformed with the principle of increasing energy flux.[33] By ingenious contrivances he has immensely refined and multiplied the operation of his receptor-effector apparatus. The excess of energy captured, over the energy barely sufficient for mere maintenance, has in his case grown to a wholly unparalleled magnitude. Normally this leaves him with a large balance available for "play" activities and luxuries. And some of his play activities have turned out to be a most profitable reinvestment. For among them must be classed scientific research indulged in primarily out of curiosity, but resulting among other things in that complete recasting of methods of production which is known as the industrial and agricultural revolution. Aside from its direct benefits this "has made it possible to spend relatively large amounts on sanitary improvements, on medical education and research, and, above all, on better living among the masses of the people. This in-

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[32] I have elsewhere (*Proceedings of the American Philosophical Society*, 1939, vol. 80, p. 625) graphically represented in quantitative measure the rocket-like ascent, in modern times, of human knowledge and technical skill. See also, the editorial "Forty Years of Plenty" in the *Bulletin of the American Association for the Advancement of Science*, 1944, vol. 3, no. 10, p. 73.

[33] Of this the exploitation of solar energy stored up from past ages in coal is in the present era the outstanding, though perhaps transitory, example. "The problem of economy in husbanding resources will not rise to its full importance until the available resources are more completely tapped than they are today. Every indication is that man will learn to utilize some of the sunlight that now goes to waste. The general effect will be to increase the rate of energy flux through the system of organic nature . . . ." (A. J. Lotka, *Elements of Physical Biology*, 1925, pp. 357-358). Compare also F. H. Pike, The Driving Force in Evolution, *Ecology*, 1929, p. 167. This also contains bibliographical notes.

crease in the productivity of human labor may, therefore, very properly be called the basis of the decline in the death rate which has taken place in almost all parts of the Western World during the last century."[34]

This is one side of the picture. But there are also less pleasing aspects. The same ingenious contrivances that extend our view, that speed our travel, and multiply our strength in beneficent pursuits, are equally potent to destroy. Then, in a world at war as today, contending armies exchange death against death,[35] while among the inhabitants of the occupied countries "a disproportionate expenditure of energy is required merely to maintain life and satisfy the most elementary demands of food and cleanliness, with the almost inevitable result that in many cases habits of personal hygiene are relaxed and all interests beyond the mere struggle for existence are stifled."[36]

It is not only in war that the trend of human evolution has brought special problems. With the vastly multiplied efficiency of modern industry, as compared with primitive labor, the necessities of life can be produced in much less than the full working time of the gainfully employed population.[37] Hence, to secure full employment much of the industrial activity must be expended on the production of luxuries and near-luxuries. This in itself would be no disadvantage. Quite on the contrary, if continued full or approximately full productive activity were assured, this would mean the enjoyment of these luxuries by the consumers, among whom are the producers themselves. But there is

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[34] W. S. Thompson, *Plenty of People*, Jaques Cattell Press, 1944, p. 64.

[35] The latest development in this field is the unlocking of atomic energy for purposes of war. It remains to be seen whether this new channel for the flux of energy through the evolving system of which human society forms part, will in the course of time be put to constructive use. In that case this will be the superlative example of the principle of maximum energy flux as characterizing the direction of evolution.

[36] International Labour Office, *The Health of Children in Occupied Europe*, Montreal, November 1943, p. 28.

[37] Compare W. B. Kaempffert, Technological Advance in Relation to Population Trends, *Proceedings of the American Philosophical Society*, 1939, vol. 80, p. 563: "In the decade from 1920 to 1930 . . . . the nation's output increased 46 percent, but the labor force only 16 percent." Compare also the editorial "Forty Years of Plenty," *Bulletin of the American Assoiation for the Advancement of Science*, 1944, vol. 3, no. 10, p. 73. In the four decades 1900 to 1940 the population of the United States increased 70 percent, while the number of farm workers *decreased* more than 10 percent.

this serious drawback: While the necessities of life, from their very nature, insistently demand continued production, no such powerful inherent drive exists for the luxury trades. And so, with our present economic system, when from time to time periods occur during which the production of luxuries and near luxuries is depressed, this results in a plague of unemployment, since idleness at such times is quite unevenly divided, some retaining full time employment, while others are wholly without work. Then we have the incongruous spectacle that in the midst of plenty there is widespread want.[38]

While the occurrence of the more severe economic fluctuations are, to say the least, annoying and do cause much hardship, it cannot be said that they offer any serious threat to the maintenance of the species, and it may reasonably be hoped that in time better adjustments of production, distribution and consumption may be achieved, with reduction or elimination of at least the more extreme fluctuations.

But the effect of the greatly increased productivity of labor in shifting the center of gravity of the total activity toward luxury production has other more serious results. It is obviously in the interest of producers to stimulate demand for luxuries. This demand, unlike that for necessities, is very elastic. The demand for personal necessities needs no particular stimulation—that is what we mean by necessities—nor could it be very greatly enhanced by any attempt at stimulation. People's appetite for food is limited. Their appetite for automobiles, radios, fur coats, jewelry, actually seems to follow the rule of the French proverb *l'appétit vient en mangeant*. At any rate it is highly susceptible to suggestion, which our advertising fraternity has developed, if not to a fine art, at least to an importunate technique.

Now overstimulation of the demand for luxuries is not without its dangers. Necessities for the species are not always felt as necessities for the individual. Few persons may be tempted to go hungry in order to buy jewels. But many actually do go without children, or without an adequate number of them, in order to maintain certain standards of

[38] The desperate measure adopted by Germany, of absorbing excess productivity by preparing for and waging aggressive war, has proved a catastrophic failure even from a criminally nationalistic point of view.

living.[39] Nature tricks the individual into doing things advantageous to the species, by linking the doing of them with pleasure for the individual. The trick works well, until the individual discovers ways of separating the links, and reaping the pleasure without accepting the cost. Here again man's ingenuity has worked against the advantage of the species, or at least of certain branches of the species, as the statistics show. The net reproduction rate, that is the ratio of total births in successive generations, has fallen well below unity, the required minimum, for many of the countries of Western civilization, as shown in Table 1.

TABLE 1

Net reproduction rate, according to age-specific mortality and fertility at specified dates*

COUNTRY	DATE	RATE
Austria	1935	.64
Belgium	1941	.67
Czechoslovakia	1935	.79
Denmark	1941	.96
England and Wales	1933	.73
	1938	.81
Finland	1938	.96
France	1939	.90
Germany	1933	.70
	1940	.98
Holland	1941	1.16
Norway	1939	.86
Sweden	1940	.79
Switzerland	1941	.90
United States (white persons)	1931–5	.98
	1939–41	1.01

* Ratio of total births in two successive generations.

The meaning of these figures is that certain contingents of mankind are headed for extinction, if present attitudes continue. This is not saying that in the case of the human species the principle of maxi-

[39] For a discussion of the social influences making for restriction in the size of families see J. J. Spengler, *France Faces Depopulation*, Duke University Press, 1938, especially pp. 157 *et seq.* Also the same author's article "Pareto on Population" in the *Quarterly Journal of Economics*, August, 1944.

mum energy flux is on the point of failing. For, in the first place, that principle contains a reservation: a maximum *compatible with the constraints*. The principle tells us what is selected; what is presented for selection is determined by other principles—just as in physico-chemical evolution the principles of thermodynamics tells us which of *possible* transformations actually take place. What transformations *are* possible is determined by the facts of stoichiometry.

Secondly, the principle of maximum energy flux presumably continues to be operative among the remaining components of the system of nature, if one of them drops out. Any species, or contingent of a species, that signally fails to keep in the current of the law of maximum energy flux is headed for elimination from the evolving system. Thus the law is preserved.

That such elimination of species occurs from time to time is a familiar fact engraved in the earth's fossil record, though the precise cause of these disappearances may remain unknown. One conjecture is that, in certain cases at least, the extinction was due to a certain fatal drift in the cumulative inheritance of certain characteristics from generation to generation by what has been termed orthogenesis. Whether physiologically speaking orthogenesis is fact or fiction is a matter of dispute, but the *exosomatic* evolution of the human species is indisputably subject to orthogenesis. Knowledge breeds knowledge, and with present-day methods of recording, this means unceasing accumulation of knowledge and of the technical skills based upon it.[40] But in a way hardly dreamed of by Tennyson, it is true that "knowledge comes, but wisdom lingers," if by wisdom we understand that adjustment of action to ends which is for the good of the species. It is precisely this that has gone awry in the schemes of men: The receptors and effectors have been perfected to a nicety; but the development of the adjustors has lagged so far behind, that the resultant of our efforts has actually been reversed. From preservation of life we have turned to the de-

[40] This property of knowledge has been much exalted by A. Korzibski (*Manhood of Humanity*, Dutton, 1921) who seemed to be under the impression that he had discovered a new principle. The idea was of course far from new. It had for example been clearly set forth by W. Ostwald in *Energetische Grundlagen der Kulturwissenschaften*, 1909, pp. 121, 122. Korzibski's characterization of man on this account, as "time binder," can hardly be praised either as a happy choice of terms or as altogether setting man apart from other species.

struction of life; and from expansion of the human race we have, in some of the most advanced communities, turned to its curtailment.

If certain contingents of the human species are to be preserved and perpetuated, a revision of prevailing valuations will be necessary. As R. S. Lillie has remarked, "The avoidance of useless conflict, and the subordination of individual interests to the integrated whole, which includes the individual, would seem to be a rational aim for conscious beings."[41] In particular, as procreation, from the essentially instinctive drive, is passing into the domain of deliberately controlled actions, it becomes necessary that the adjustment of reproduction be equally controlled in accordance with the needs of the species. This may be difficult to accomplish. For, as Whelpton has pointed out, "The average size of planned families has been substantially smaller than that of unplanned families in the past and will be smaller in the future, though perhaps in lesser degree. Any tendency for the average size of planned families to increase in the future will be more than offset by the increase in the relative frequency of planned families which will result from the continuing spread through the population of information about effective methods of contraception."[42]

We find ourselves at a most remarkable epoch in history. As never before, man looking back contemplates a vista of miraculous progress; and as never before he finds himself casting searching glances into the future. Our gratification in being at once spectators and participators in a captivating drama is considerably damped by the fact that the prospect does not please. In the solution of scientific and technical problems we have achieved brilliant results. Social problems, as conceived broadly from the point of view of the species, we have bungled.

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To us, at this critical period, the two-fold threat to the very existence of large sections of the human race dominates our immediate interest in world history. In the longer view all this is but an episode in the great drama of the evolution of the earth and its inhabitants. The

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[41] R. S. Lillie, The Psychic Factors in Living Organisms, *Philosophy of Science*, 1943, vol. 10, p. 270. Similar reflections also are developed, especially in the closing chapters, in my *Elements of Physical Biology* (1925).

[42] P. K. Whelpton, War and the Birth Rate. Paper presented before the American Public Health Association, Oct. 2, 1944.

larger scientific outlook aspires to an objective survey of events quite aside from any peculiar relation which they may have to human affairs.

It is with this broader conception that we have viewed the evolution of life on our planet as the changing distribution of matter among the various organic species and their inorganic environment. Whatever line the development of this branch of science may ultimately take, this can be confidently asserted, that no treatment can be effective which fails to give a prominent place to the competition for substance and energy among the diverse organic species, in relation to the characteristic physical and dynamical properties which the individual organism possesses for waging the competitive struggle. We may further set it down that the formulation of the law of evolution must unquestionably be made in terms of the evolving system as a whole; that it cannot be adequately expressed by reference to only one component, such as a single species. It is the system as a whole, under the flood of light energy received from the sun, that evolves. From our experience in the disciplines of the physics of change of state and physical chemistry we know that it would be quite out of the question to formulate the law of evolution of a physico-chemical system by reference to one of the components alone. No more can we expect to express the basic directional principle of organic evolution in terms of the "organization" or any other property or assemblage of properties of individual species considered separately. It is in the collective activities and effects of the organisms that we must look for an indication of the direction of evolution. These collective effects tend to maximize, on the one hand, the energy intake of organic nature from the sun, and on the other, the outgo of free energy by dissipative processes in living and in decaying dead organisms. The net effect is to maximize in this sense the energy flux through the system of organic nature.

Such, it seems, is the shape of the basic principle defining the direction of organic evolution.

THE RH BLOOD FACTOR AMONG TWINS*

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THE Rh blood factor was discovered in 1940 by Landsteiner and Wiener (2) as a consequence of testing human blood with anti-Rhesus monkey serum. Hence the name Rh. According to their results about 85 per cent of all white (Caucasoid) individuals are Rh positive (Rh +) and about 15 per cent are Rh negative (Rh —).

In 1941 the same investigators (3) reported that Rh variations have a hereditary basis. In fact, they concluded that these variations are completely determined genetically. The Rh positive condition they found to occur when an individual possesses an autosomal dominant gene, which they appropriately called *Rh,* and the Rh negative condition when an individual is homozygous recessive *rh rh.* These conclusions were based on an examination of 60 families with 237 children. In 1943 Wiener and Sonn (11) added 40 families with 138 children. Their results supported the genetic conclusions of Landsteiner and Wiener.

Recently evidence has been obtained that subdivisions of the Rh factor occur and that these also have a hereditary basis. According to Wiener (10) six Rh alleles exist, instead of only two as was suggested originally.

During the past two years Professor L. L. Thurstone, of the Psychology Department of the University of Chicago, and the senior author of the present paper have been investigating the extent to which variations in certain psychological traits have a genetic basis. This investigation involved the testing of 120 pairs of same-sex twins recruited from the Chicago Public Schools.[1] One of the essential preliminary steps in

* This study was supported in part by a grant from the National Research Council through its Committee on Human Heredity.

[1] We are indebted to the Chicago Public School Administration and to the many twins who participated in our study for their gracious and valuable cooperation.

this study was a determination of the zygosity of the twins. The usual criteria of physical resemblances and fingerprints were employed. In addition, the well known A-B and M-N blood groups were taken into account. Utilized also were "secretor," color vision, and taste reaction tests. On a basis of all of these criteria 56 of the 120 sets of twins were diagnosed as monozygotic or "identical" and 64 as dizygotic or "fraternal."

With 56 monozygotic and 64 dizygotic pairs of twins available it seemed of interest to examine them with respect to the Rh blood factor, and thereby to test (1) the degree of genetic determination of Rh variations, and (2) the manner in which these variations are assumed to be inherited. When the twin study was begun the only serum procurable was "standard" Rh human serum which gives about 85 per cent positive and about 15 per cent negative reactions among white individuals. Accordingly our Rh tests pertain only to the positive and the negative types which this serum reveals.[2]

Eight sets of the 120 diagnosed twin pairs were not tested for the Rh factor, since anti-Rh serum was not on hand at the time these twins came to the laboratory. The 120 pairs of twins appeared over a period of more than a year, because both psychological tests and physical measurements were extensive and required at least one full day per twin pair in our laboratory as well as one full day in the public school system. Of the 112 pairs tested for the Rh factor 53 were monozygotic and 59 dizygotic.

The results of the Rh tests on these 53 monozygotic and 59 dizygotic twin pairs are presented in Table 1. From an inspection of this table it will be seen that in every case the two members of the 53 monozygotic sets were either both Rh positive or both Rh negative. This perfect concordance with respect to the Rh factor among monozygotic twins supports the conclusion that the originally discovered Rh variations are completely genetically determined. The family studies, particularly the results of matings between two Rh negative individuals, had suggested this, but had not proved the point entirely satisfactorily. In fact there should probably be more evidence than is as yet available before we may

[2] It is a pleasure to express our appreciation to Dr. A. S. Wiener and to Dr. I. Davidsohn for helpful suggestions relative to Rh testing techniques. The serum which was used was obtained from the Certified Blood Donor Service, Jamaica, New York.

feel absolutely certain that a given Rh phenotype always corresponds to a given Rh genotype. Certainly we must be positive of this relationship if we are to recommend Rh tests as legal evidence in disputed parentage cases, and also if we are to use Rh tests as criteria in the diagnosis of twins.

TABLE 1

Observed numbers of the different possible Rh combinations among 112 sets of twins

TYPE OF TWIN SET	NUMBER OF SETS TESTED	BOTH MEMBERS RH +	ONE RH +, OTHER RH —	BOTH MEMBERS RH —
Monozygotic	53	45	0	8
Dizygotic	59	49	5	5
Total	112	94	5	13

The two members of the 59 dizygotic twin sets were of the same Rh type in some pairs and different in others. These concordance and discordance results among dizygotic twins are not, in and of themselves, direct evidence that the originally discovered Rh variations are completely genetically determined, but they are in agreement with expectations based on this hypothesis.

As stated above we are interested, not only in examining the degree of genetic determination of the originally discovered Rh variations, but also in testing the mode of inheritance which was suggested for them by Landsteiner and Wiener. The latter can be done to some extent by comparing statistically the observed relative frequencies of the different types of Rh combinations among both monozygotic and dizygotic twins with the frequencies expected according to the proposed mode of inheritance.

The expected percentages of the different Rh combinations among monozygotic and dizygotic twin pairs depend upon the expected phenotypic frequencies of the population from which the twin sets are drawn. Most of the twin sets which we tested were white, but they did include 15 Negroid pairs. Negroes have a much lower incidence of Rh negative than do whites. Therefore these two racial groups must be considered separately. What we have done in this study is to examine only the

frequencies among the white twins, because the 15 Negroid sets constitute too small a sample to warrant an independent statistical comparison of their observed and expected frequencies.

The expected percentages of white monozygotic twin pairs, in which both members are Rh positive and both are Rh negative, are the expected percentages of Rh positive and Rh negative individuals in the white population, or in this instance 85 per cent and 15 per cent respectively. (Although these percentages may not be exactly correct we shall accept them as such for calculation purposes.) The expected percentages of the different Rh combinations among dizygotic twin pairs are not quite so obvious, but they can be derived easily by a consideration of estimated gene, genotypic and mating frequencies within the population.

The estimated gene frequencies in the population may be calculated as follows: The best estimate of the frequency of the recessive *rh* gene in the white population is the square root of the frequency of the homozygous recessive phenotype, that is, the square root of 15.00 per cent which is 38.73 per cent. The best estimate of the frequency of the dominant *Rh* gene is 1 minus the frequency of its recessive allele, that is, 1 minus .3873 or .6127 which is 61.27 per cent. Thus the estimated gene ratio in the white population is 61.27 per cent *Rh* to 38.73 per cent *rh*.

The estimated genotypic ratio in a population mating at random is the square of the gene frequency or in this instance $(.6127\ Rh + .3873\ rh)^2$ which is 37.54 per cent *RhRh*: 47.46 per cent *Rhrh*: 15.00 per cent

TABLE 2

Expected percentages of Rh matings and Rh offspring in white population

POSSIBLE RH MATINGS	PROPORTION OF EACH TYPE OF RH MATING		PERCENTAGE OF EACH RH TYPE AMONG ALL OFFSPRING Rh +	Rh −
Rh Rh × Rh Rh	$.3754^2$	= .1409	14.09	0.00
Rh Rh × Rh rh	$2(.3754 \times .4746)$	= .3564	35.64	0.00
Rh Rh × rh rh	$2(.3754 \times .1500)$	= .1126	11.26	0.00
Rh rh × Rh rh	$.4746^2$	= .2252	16.89	5.63
Rh rh × rh rh	$2(.4746 \times .1500)$	= .1424	7.12	7.12
rh rh × rh rh	$.1500^2$	= .0225	0.00	2.25
Total		1.0000	85.00	15.00

rhrh. From this genotypic ratio the expected percentages of the different Rh combinations among dizygotic twins can be determined. The steps followed in their calculation are shown in Tables 2 and 3.

TABLE 3

Expected percentages of the different Rh combinations among white dizygotic twins

MATING	PROBABILITY OF OFFSPRING WITHIN A FAMILY		PROBABILITY OF EACH RH COMBINATION AMONG DIZYGOTIC TWINS WITHIN A FAMILY			PERCENTAGE OF THE DIFFERENT RH COMBINATIONS AMONG DIZYGOTIC TWINS		
	Rh+	Rh—	Both Rh+	One Rh+, other Rh—	Both Rh—	Both Rh+	One Rh+, other Rh—	Both Rh—
Rh Rh × Rh Rh	1	0	1	0	0	14.09	0.0	0.0
Rh Rh × Rh rh	1	0	1	0	0	35.64	0.0	0.0
Rh Rh × rh rh	1	0	1	0	0	11.26	0.0	0.0
Rh rh × Rh rh	3/4	1/4	9/16	6/16	1/16	12.67	8.44	1.41
Rh rh × rh rh	1/2	1/2	1/4	2/4	1/4	3.56	7.12	3.56
rh rh × rh rh	0	1	0	0	1	0.0	0.0	2.25
Total						77.22	15.56	7.22

In Table 4 are given the frequencies of the observed and the expected Rh combinations among both the monozygotic and the dizygotic twin pairs. A cursory examination of the table reveals a close agreement between observed and expected percentages. If we apply a chi square test to the data for the monozygotic twins we obtain a chi square value of .017 which, with one degree of freedom, has a probability between .95 and .50. The dizygotic data (comparing like versus different Rh types) give a chi square value of .70 which has a probability between .50 and .30. Thus we find that the observed frequencies of Rh combinations among both the monozygotic and the dizygotic twin pairs are within theoretical expectations. Hence we may conclude that they support the unifactorial mode of inheritance proposed by Landsteiner and Wiener.

Another way in which a comparison can be made between observed and expected frequencies is to consider a pair of monozygotic twins a single individual and a pair of dizygotic twins as two. If this is done and the frequencies of Rh positive and Rh negative individuals are re-

corded we obtain the data presented in Table 5. An inspection of this table will reveal that the observed frequencies are very close to the expected. A chi square test is not appropriate here without a considera-

TABLE 4

Observed and expected frequencies of Rh combinations among white twins

	NUMBER TESTED FOR RH	BOTH MEMBERS RH +		ONE RH+, OTHER RH—		BOTH MEMBERS RH —	
		Number	Percent	Number	Percent	Number	Percent
		Monozygotic					
Observed	48	40	83.33	0	0	8	16.67
Expected		40.80	85.00	0	0	7.20	15.00
		Dizygotic					
Observed	49	40	81.63	5	10.20	4	8.16
Expected		37.84	77.22	7.62	15.56	3.34	7.22

TABLE 5

Observed and expected percentages of Rh positive and Rh negative individuals among white twins (A monozygotic set is considered one individual)

	RH POSITIVE				RH NEGATIVE			
	Number		*Per Cent*		*Number*		*Per Cent*	
	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.
White individuals	125	124.1	85.62	85.00	21	21.9	14.38	15.00

tion of special points, but even though we do not prove statistically that the agreement is close we may conclude as before that the observed frequencies support the proposed unifactorial mode of inheritance.

Although we have already concluded that the observed frequencies of the different Rh combinations among twins are in good agreement with those expected according to theory it is appropriate that we examine any factor which conceivably might affect expected percentages. This

is especially important since the expected percentages of Rh combinations as calculated for both monozygotic and dizygotic twins are percentages as expected at time of conception, whereas the twins tested are of high school age. One such possible factor is erythroblastosis fetalis. This disease, it will be recalled, frequently is fatal and occurs in Rh positive fetuses which have an Rh negative mother (Levine, 6, 7).

As shown by Table 2 about 9 per cent of all white children should be Rh positive and have an Rh negative mother [½ (11.26% + 7.12%) or 9.18%]. Hence that many children are potential erythroblastotics. Fortunately, the disease is not this common. Accordingly to Potter (8) it develops in only about 1 in 40 infants for whom the possibility of its occurrence exists, that is in only about 2.5 per cent. On the basis of the foregoing information its incidence among all births is about 0.23 per cent.

Without presenting details we may state that we have calculated the possible effect of erythroblastosis and find that the disease should not alter the expected percentages of any Rh combination among twins by as much as .1 per cent. This low figure is obtained even if we assume that all erythroblastotic infants die, which is not quite true. Thus the effect of erythroblastosis in so far as it relates to our analysis may be ignored. In fact, it would be folly to correct for an effect of this small magnitude because the error in the estimation of the expected percentages is likely to be as large as or larger than 1 per cent.

No other factor is known to us which conceivably might affect the expected percentages. Hence the conclusions which we have drawn on the basis of our comparison of observed and expected percentages seem valid.

We may now summarize our conclusions relative to the genetics of the Rh factor as follows:

1. The perfect concordance in the Rh factor among 53 pairs of monozygotic twins lends credence to the point of view that Rh variations are completely genetically determined. This hypothesis had been advanced by Landsteiner and Wiener on the basis of the results of family studies but it had not been substantiated entirely conclusively. There should probably be more evidence than we have even now before we recommend Rh tests as evidence in legal cases involving disputed parentage.

2. The observed percentages of Rh combinations among 48 monozygotic and 49 dizygotic white pairs of twins are in good agreement with expectations based on the unifactorial mode of inheritance proposed by Landsteiner and Wiener. They therefore may be said to support this mode. No examination was made relative to the genetics of the recently discovered Rh subdivisions.

Since all evidence obtained so far suggests that the originally discovered Rh positive and Rh negative types are completely genetically determined, and also that they follow a unit factor Mendelian mode of inheritance, it is of interest to evaluate the use in the future of these Rh variations as criteria for the diagnosis of twins. Twins are being used more and more in human genetic studies and it is important that we be able to diagnose correctly all sets encountered. This can now be done fairly satisfactorily but not always on a strictly objective basis. We need all the new objective criteria that we can muster.

According to the conclusions which have been drawn a pair of twins must be dizygotic if they are of different Rh types. About 15.56 per cent of all dizygotic twins in the white population should consist of an Rh positive and an Rh negative member (see Table 4). About 66 per cent of all white twins are dizygotic, consequently we should be able to diagnose as dizygotic on the basis of Rh tests alone 15.56 per cent of 66 per cent or about 10.27 per cent of all white twins.

In actual practice the Rh test would probably be used for diagnostic purposes only for twin pairs of like sex, because twins of opposite sex are immediately considered dizygotic. All monozygotic twins (that is, about 34 per cent of all white twins) and about one half of all dizygotic twins (which means about 33 per cent of all white twins) are of the same sex. This gives a total of about 67 per cent of all white twins which are of the same sex. About one half of the 10.27 per cent, or 5.14 per cent of all white twins are of different Rh type and fall in the group of same-sex twins. Therefore, about 7.67 per cent of all same-sex white twins should be of different Rh blood type, and therefore diagnosable as dizygotic on the basis of Rh tests alone. (The percentage diagnosable should be considerably larger when tests for recently discovered Rh subgroups are added.)

If the two members of a pair of twins are of the same Rh type they cannot be said with certainty to be either monozygotic or dizygotic on the basis of Rh tests alone, but it is possible to indicate the probability

that they are the one or the other. These probabilities are different for sets in which both members are Rh positive from what they are for sets in which both members are Rh negative. The probabilities are also different, of course, among twin pairs of like sex from what they are among twin pairs irrespective of sex. All of these probabilities have been calculated and are shown in Table 6.

TABLE 6

Percentage of white twins diagnosable as dizygotic on the basis of Rh tests, and the probability that a set of twins of same Rh type is monozygotic or dizygotic

CATEGORY	PERCENTAGE DIAGNOSABLE AS DIZYGOTIC	BOTH MEMBERS RH+			BOTH MEMBERS RH—		
		Per cent expected	Probability		Per cent expected	Probability	
			Monozygotic	Dizygotic		Monozygotic	Dizygotic
All white twins	10.27	79.86	.36	.64	9.87	.52	.48
All same sex white twins	7.67	81.16	.53	.47	11.17	.68	.32

We concluded above that erythroblastosis does not affect appreciably the expected percentages of Rh combinations among twins between time of conception and high school age. Although this is true, it is of interest to review some of the cases of erythroblastosis among twins which have been reported in the literature, because they present unique information relative to the etiology of the disease. In 1943 Kariher (1) reported a set of twins in which one member was Rh positive and erythroblastotic and the other was Rh negative and normal. The mother of this pair of twins was Rh negative and the father Rh positive. A similar case was published by Potter (9) in 1944. Levine, in his reviews of erythroblastosis (4, 5) refers to two other like cases; the one was observed by him, the other by Guest (not published). All of these cases are of interest in that they present some of the best evidence which exists in favor of the view that erythroblastosis is the result of

Rh antibodies developed in an Rh negative mother acting on Rh substances in an Rh positive fetus. As Potter (8) has pointed out these cases also illustrate uniquely the fact that an Rh negative child, in the same environment in which an Rh positive fetus develops erythroblastosis, will not show any signs of the disease.

Although only a few dizygotic twins have been reported in which one member was erythroblastotic and the other was not, the occurrence of such sets in the white population of the United States should not be exceptionally rare. From an inspection of Table 3 it will be seen that one-half of 7.12 per cent or 3.56 per cent of all dizygotic twins in the white population should consist of an Rh positive and an Rh negative member and have an Rh positive father and an Rh negative mother. Of course not all of these Rh positive members of dizygotic twin sets should develop erythroblastosis, since according to Potter, the disease develops in only about 2.5 per cent of all potential cases. The percentage expected is close to 2.5 per cent of 3.56 per cent or close to .09 per cent. This may not seem like a large number, but since there are about 14,000 dizygotic twin sets born to the United States white population each year we should expect from 10 to 12 such dizygotic sets annually. It will be of interest to learn whether this many sets of this particularly interesting combination actually appear.

SUMMARY

1. Fifty-three monozygotic and 59 dizygotic pairs of twins were tested for the originally discovered Rh factor. (Tests were not made for the newly discovered subdivisions of the Rh factor.)
2. The two members of the 53 tested monozygotic sets were in every instance of the same Rh type. This perfect concordance among monozygotic twins leads credence to the conclusion that the originally discovered Rh variations are completely determined genetically.
3. The two members of the 59 tested dizygotic sets were both Rh positive in 49 pairs, both Rh negative in 5 pairs, and different in 5 pairs. Although these results are not direct evidence for complete genetic determination of Rh variations they agree with expectations based on this conclusion.
4. The observed frequencies of the different Rh combinations among both monozygotic and dizygotic twin pairs are compared statistically with those expected according to the proposed unifactorial mode

of inheritance of Landsteiner and Wiener. The agreement between the two sets of data is close. Hence we may conclude that the observed frequencies support the proposed mode.

5. The effect of erythroblastosis on the percentages of Rh combinations expected among twins between time of conception and high school age is examined. It is found to be negligible and that no correction for it is warranted.
6. The Rh factor is evaluated as a criterion for the diagnosis of twins. It is shown that about 10 per cent of all white twins and about 7.7 per cent of all same-sex white twins, should be diagnosable as dizygotic on the basis of Rh tests alone.
7. The occurrence of erythroblastosis in twin pairs in which one member is Rh positive and the other is Rh negative is briefly reviewed. It is estimated that from 10 to 12 such sets of twins should occur annually in the white population of the United States.

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STUDIES IN THE PHYSICAL DEVELOPMENT
VII. ENVIRONMENTAL TRENDS AMONG THE AMERICAN NEGRO

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INTRODUCTION

THE present paper was conceived as a general background for the other parts in this series. It goes almost without saying that since the advent of the war the conditions reported herein have been influenced by many factors among which changing employment opportunities on the home front rank high.

In trying to evaluate the significance of the findings detailed in the previous sections, I should like, first, to make a brief reference to a theoretical consideration, namely to the problem whether the secular increase in height and weight and also the acceleration of the onset of puberty detected among children of the poor Negro population of New York City might possibly have taken place irrespective of environmental factors. However, the difficulty in answering this question in favor of heredity lies in the fact that a hypothetical intrinsic tendency towards an increase in stature or speeding up of sexual maturity cannot be appraised unless environmental factors are ruled out as a potent cause. We are in no position to rule them out. On the contrary, a survey of the socio-economic status of the Negro population ought to disclose improvements in their mode of living.

Such changes have occurred with the progress in the fields of nutrition, health education, public health and sanitation, and of public welfare.

The aim of the present paper is to describe some of the important socio-economic events in the Negroes' mode of life.

As to the source material, the bulk of the data was extracted from recent publications and supplemented by information emanating from

the Department of Health of New York City and that of the Jefferson County Board of Health, Birmingham, Alabama.

The report dealing with the nutritional regime in the clinics of the Department of Health of New York City was prepared by Dr. Nellie Marmor.

In reviewing those environmental trends which represent a tangible progress in the Negroes' mode of life, the time period embracing the last two and a half decades was considered; however, the most recent decade received special attention. This investigation is very fragmentary, and the reasons for it are being explained in the text.

Three items, nutrition, health and public assistance, are the basic themes of the study. An attempt was also made to use the prolongation of the life span in a Southern and Northern city as a hypothetical indicator of environmental changes as a whole, including improvements. The rationale of the procedure employed is stated in the text.

In the section dealing with health, two diseases have been singled out, tuberculosis and syphilis. It has been known for a long time that the mortality rate from tuberculosis for the Negro is considerably higher than that for the white (though the ratio between both races is not one and the same among the comparable age groups and varies in different localities). Studies in epidemiological trends have brought out the fact that tuberculosis mortality can in most areas be correlated with socio-economic conditions. In view of the greater poverty of the Negro, it was interesting to examine the facilities available to the latter in the field of tuberculosis control.

As far as syphilis is concerned, its prevalence in this country has been clarified so recently that the inclusion of this subject matter in the discussion of environmental factors seems to be timely.

The present investigation intends to elucidate the following questions:

First, how is the nutrition of the Negro children being attended to?

Second, what progress can be recorded in the general health of the Negro for the past quarter of the present century?

Third, what is the status of the Negroes' two main disease scourges, tuberculosis and syphilis, from the point of view of their control?

Fourth, through what means is the progress in the Negroes' living conditions being enhanced?

Fifth, can one evaluate the totality of environmental changes, including improvements, among whites and Negroes for the decade preceding the present war, by using the life span as a yardstick?

NUTRITION

The distribution of free food by municipal and federal subsidy constitutes a major effort to meet the needs of the underprivileged, white and colored. The Annual Report of the Department of Welfare, New York City, ('39 - '40) records the distribution of free milk to 133,000 children under sixteen in relief families; and this program is supplemented by other programs which provide free milk in schools and also permit buying milk in the schools at one cent for half a pint. Under this plan 715,000 city children are buying milk daily.[1]

The assistance given to the infants of the poor population by the Department of Health clinics warrants a detailed report. I have already mentioned that this care suggests a correlation between the nutritional aspect and an increase in height values in children. While voicing such an opinion, I unreservedly admit that none of the specific factors which have caused an increase in stature or acceleration in growth during the more recent period can be identified. All that can be said is that nutrition seems to play an important role.

The following is an account of the supervision by the Department of Health of New York City over the impecunious children of the Harlem District. This nutritional regime, crystallized about 1934, has a special interest for the present study because that care was followed through in dealing with those children whose average stature surpassed that attained by the same age groups measured in 1919.

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[1] An example pertaining to the South is of interest. The *Birmingham News* reported ('42): "Free lunches, prepared from surplus commodities distributed by the State Department of Public Welfare, are being provided for some 67,300 Alabama school children." However, the same paper reported ('43): "After April recipients of public assistance in Alabama will not have their monthly grants supplemented by surplus foods from the U. S. Department of Agriculture. The Welfare Commissioner of Alabama cited food shortages, closing of state WPA projects that furnished personnel for distribution, and transportation difficulties as reasons for closing the service, which had been handled through the Welfare Department. Since the program's inception in October, 1933, approximately $22,000,000 worth of commodities have been distributed to needy Alabamians."

I quote from a communication by Dr. Nellie Marmor:

In conducting our clinic we endeavored to attain the best knowledge in the principles and ideas on the proper growth and development of babies, and to transmit our concepts in as simple a form as possible to the mothers.

The white babies came from self sustaining but fairly poor homes, families where pennies counted.

The colored babies came from families of subsistence level, 80 per cent of which were carried by one or another of the relief agencies. They lived in more crowded homes than our white babies and ran the risk of more health hazards. They were referred to us by hospitals and other agencies. Some of the babies' mothers came of their own accord.

In 1934, we sent out a field worker to visit 200 families. She jotted down the mothers' report on the feeding of the baby on that day. This was then compared with her instructions as given by the doctor. In 91 per cent of cases the mother at least understood our instructions and in all probability carried them through.

In the spring of 1934 when irradiated evaporated milk first appeared on the market, we placed a number of babies on formulae prepared with the same. A nurse visiting the homes of each of these mothers found the prescribed brand in each and every home. The grocers in the neighborhood (Harlem, New York City) carried the irradiated brand because the mothers demanded it. A check up in other neighborhoods proved that it was as yet unknown there.

A study of 1000 new admissions for the year 1935 in Harlem furnishes the following data on Negroes:

82 came in very poor physical condition
215 came in fair physical condition
703 came in good physical condition
379 were first babies
621 were not first babies

Age groups on admission:

Up to 1 month	198
1 month but not 2 mos.	482
2 mos. but not 3 mos.	123
3 mos. but not 4 mos.	48
4 mos. but not 5 mos.	31
5 mos. but not 6 mos.	12
6 mos. to 12 mos.	47
1 - 2 years	57

A study of 1,000 white babies on admission furnishes the following data:

74 admitted in poor condition
177 admitted in fair condition

749 admitted in good condition
520 were first born babies
480 were not first born babies

Age groups on admission:

Up to 1 month	314
1 month but not 2 mos.	335
2 mos. but not 3 mos.	115
3 mos. but not 4 mos.	78
4 mos. but not 5 mos.	32
5 mos. but not 6 mos.	31
6 mos. to 12 mos.	81
1 - 2 years	24

There were many more first-born babies in our white than in our Negro group, and more white babies were placed under supervision at a younger age.

In both groups of babies we carried on the following program: Up to three months of age we asked the mothers to bring the baby to the clinic every 2 weeks; from 3 months to 1 year once a month; and from then on once in 2 months.

Instructions were given by the doctor and checked by the nurse.

By these frequent check-ups and visits we made sure that orders were properly understood, that sufficient cod liver oil was given and retained, that the baby was progressing properly.

Physical examinations were made on admission to the clinic. Babies with gross pathologic conditions were referred to the proper agencies for care. The babies were re-examined at stated intervals and when necessary.

Wherever possible we kept the babies breast fed. We impressed the mother with the fact that this was the cleanest, the safest, the cheapest, and best protective food for the baby. We checked to see how this was carried through. We found that in Harlem, where some of the mothers go out on part time jobs, 51 per cent of the Negro 5-months-old babies were breast fed. Among the whites some of the mothers came to us because they no longer had breast milk; and 32 per cent of the white 5-months-old babies were breast fed. All babies were weaned at 7 or 8 months of age.

Where breast milk was impossible, we ordered irradiated evaporated milk diluted with water, cane sugar or karo syrup added. Each formula was prescribed according to the age, weight and condition of the baby. If evaporated milk was not tolerated, other formulae were ordered.

Orange or tomato juice was prescribed on the first day of registration.

Cod liver oil was prescribed on the first visit. We ordered full amounts of cod liver oil for our colored babies during the summer

months; whereas for the white babies we reduced the amount of cod liver oil during the summer. We ordered cod liver oil wherever possible. Where it was not tolerated or counter-indicated, we prescribed other vitamin D products.

Supplementary Vitamin-rich foods were added as the baby was old enough to assimilate the same. At the request of the clinic the Red Cross printed slips for the preparation of the supplementary foods.

We kept an eye on the market and ordered the foods in season; those cheapest at the time; for pennies are of vital importance to these mothers. No expensive drugs, etc. were ordered if cheaper ones could do as well.

Practically all the babies in both groups were vaccinated and inoculated against diphtheria during the first year. Schick tests were performed during the second year.

About 50 per cent of our colored babies had had at least one Wassermann test. The second year babies had had a Mantoux test the year before.

Mothers in both groups were instructed to permit their children to develop according to their individual patterns, psychologically and physically. No constrictions or bands of any kind were permitted. The aim was as much freedom of motion as possible. All babies were allowed to sleep in any position they chose to assume;[2] to sit up when ready to sit up, to walk when ready to walk.

In 1935 it was found that of the babies who had reached one year of age, 83 per cent had not had one day of fever, except following vaccination.

The morbidity among the colored babies was higher than that of the white babies, easily explained by their crowded home conditions.

The colored group presented less behavior problems than the white babies. In general, there was a very happy relationship between babies and mothers.

From all the forementioned it becomes evident that the existence of environmental improvements in the mode of life of the Negroes cannot be discounted in considering influences which affect physical development.

It remains to be seen whether, or to what degree, a possible food shortage due to the present war, may affect physical growth. Experts on nutrition[3] hold the opinion that at present rickets leads among the

[2] This statement is noteworthy in view of the fact that Negro children supervised in the described manner, were discussed in the section dealing with the cephalic index. See: *Am. J. Phys. Anthrop.* (N. S.), 1943, V. 1, No. 4, Dec.

[3] These opinions were expressed during a conference devoted to deficiency diseases, held in the Hillman Hospital, Birmingham, Alabama, June 1943.

deficiency diseases diagnosed in Negro children of the South, this malady being less prevalent among whites of the same area. On the other hand, the totality of deficiency diseases observed in whites, both children and adults, is said to amount to 95 per cent as against 5 per cent in Negroes. It is still an open question whether the deficiency diseases, except for manifest rickets, are more difficult to diagnose in the Negro than in the white or whether whites have a greater racial vulnerability to the effects of food deficiency. Possibly other still unknown factors partake in this perplexing racial distribution of deficiency diseases as ascertained thus far.

HEALTH

Organized health education among Negroes took a definite form when the Public Health Service issued "The National Negro Health Week Bulletin." I quote from the United States Public Health Service ('40):

> "The National Negro Health Week Bulletin has been issued by the Public Health Service since 1921. Since 1932 the Service has furnished quarters and operating facilities for this office, and since 1934 a director and clerical assistant have been provided. Each year a National Negro Health Week is observed, during which community educational programs are presented. Health lectures, sermons, and radio talks are given; demonstrations, pageants, and motion pictures presented; physical examinations, health instructions, and medical services given. A poster and school leaflet are also published each year in connection with the Health Week. Civic leaders and others are encouraged to promote a year-round follow-up of Health Week plans. The National Negro Health News, a quarterly bulletin of health information for racial and interracial groups, published by the Office of Negro Health Work, has a wide distribution and stimulates continued interest in health and community sanitation.
>
> "The field service, advice, and health publications provided by the Public Health Service through the Office of Negro Health Work contribute in large measure to the health consciousness of the Negro and his integration in the health programs of his particular state and community."

The improvement in the Negroes' mortality rate has been demonstrated by Dublin and Lotka ('37). I quote:

> "A remarkable decline in the mortality of the American Negro has taken place in a little less than two decades. In 1911, the standardized mortality rate of the colored industrial policyholders of the

Metropolitan was 18.5 per 1,000. In 1935 the death rate of these insured Negroes had declined to 11.8, which represents a drop of 36 per cent in this period.

"This marked decline is due, for the most part, to improvements in the death rates from tuberculosis, pneumonia, malaria, typhoid fever, diphtheria, diarrhea and enteritis, and pellagra. Particularly noteworthy has been the great development of health activities in the South[*] and Southwest. The betterment has been a broad one, affecting virtually all areas, with scarcely a State failing to show a decided decline in the total death rate. While it is true that the mortality among Negroes is still high, reflecting marked deficiencies in the health provisions for them, we cannot but conclude that the public health movement is making a favorable impress upon our colored population.

"The general improvement in the death rate is, of course, reflected in the figures for expectation of life. In the two years 1911 - 1912 the expectation of life for Metropolitan colored male policy-holders at age 10 was 41.32 years; in 1935 the expectation was 46.97 years, an increase of almost 6 years, or 14 per cent. The expectancy of Negro females at age 10 was 41.30 years in 1911 - 1912 as compared with 49.38 in 1935. This is a gain of 8 years, or 20 per cent, which is a better record than the increase of 7 years, or 14 per cent for insured white females. There can be no mistake in the conclusion that the last 25 years have seen a pronounced improvement in the health situation of the colored people; and this, despite the fact that these years included the periods of the war, of the influenza epidemic, and of the recent economic depression, as well as an immense migration to Northern cities, often undertaken under the most unfavorable conditions."

Comparing Negroes with whites, Dr. Louis I. Dublin states:

"At every age period, from infancy to old age, and for each sex, the death rate for colored persons is in excess of that for whites.

"The Negro death rates for practically all diseases in which care and sanitation are of paramount importance are much higher than among whites. It is probable that their higher death rate is due more than anything else to ignorance, poverty, and lack of proper medical care. Pulmonary tuberculosis, typhoid fever, pellagra, malaria, and puerperal conditions are examples of such diseases in which the mortality rates are much affected by unfavorable or insanitary environment—or by low economic status—and all of them have higher death rates among Negroes.

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[*] On May 14th, 1942, the Alabama State Department of Health reported: "The 1930 death rate for Negroes was 15.2 per 1000 population and that for 1940 14.1 per 1000. The 1940 Negro typhoid death rate dropped 78.2 per cent below that of 1930; the whooping cough rate was 46.3 per cent lower than 1930, and the diphtheria, 64.3 per cent lower. The fatality rate for tuberculosis among Negroes was found to be 38 per cent less than the 1930 rating; for malaria, 33.2 per cent less, and for pellagra, 67.8 per cent less.

> "I doubt whether we really know just what part of the higher mortality of the Negro is attributable to racial susceptibility and what part to the effects of racial customs and environmental conditions."

Through the courtesy of Mr. Thomas J. Duffield, Registrar of Records of the Department of Health of New York City, I obtained information on the death rate for four decades and the median age at death among Negroes in New York City from 1920 to 1940. Table 1 shows that in 1920 the median age at death was 29.2 years, and two decades later 45.6 years. The same table shows also that the death rate for all causes was 30.1 per 1000 population in 1901, and 12.2 four decades later. It must be remembered that the age distribution of a population is an essential element in the total death rate. The figures in Table 1 were not corrected in accordance with that consideration, as this approach was beyond the scope of the present investigation.[5]

The decrease of the general death rate in the more recent epoch is due mainly to the reduction of acute infectious diseases. However, during the same period of time the mortality from chronic diseases has risen, accounting for one-half of all deaths occurring at present.

The decrease in all kind of infectious diseases and also a diminished birth rate have caused an aging of the population. Since the turn of the century the population above 45 years of age has more than doubled; and this increase of the older age groups[6] is one of the reasons why more persons are afflicted with chronic diseases. Though chronic disease affects all age groups—one-half of the persons afflicted are under 55 years—its prevalence increases with age.

Thus the increase of longevity has presented medicine with a new challenge, namely, to find the means of reducing chronic diseases. The trend toward a population of old people and the concomitant increasing mortality from cancer, the degenerative diseases of the circulatory system and the kidneys, are focusing the physicians' attention more and more on geriatrics, i. e., the care of the aged (Boas and Michelson '29; Boas '40; Stieglitz '43).

The correlation between illness and economic status was shown by Holland and Perrott ('38). Among other things, they found that the

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[5] A discussion of the median age at death will be found in the last part of the present paper.

[6] In 1900, 44 per cent of our entire population was under 20 years of age; and in 1940, 34 per cent. Quoted from: *Facts about Child Health,* U. S. Department of Labor.

TABLE 1

Population, deaths and death rate from all causes, and the median age at death among Negroes in New York City, 1901-1940*

YEAR	POPULATION	NUMBER OF DEATHS ALL CAUSES	DEATH RATES ALL CAUSES*	MEDIAN AGE AT DEATH
1901	63,961	1,927	30.1	
1902	67,117	1,997	29.8	
1903	70,273	1,744	24.8	
1904	73,430	2,376	32.4	
1905	76,586	1,997	26.1	
1906	79,742	2,056	25.8	
1907	82,898	2,319	28.0	
1908	86,054	2,212	25.7	
1909	89,210	2,176	24.4	
1910	93,013	2,303	24.8	
1911	99,271	2,370	23.9	
1912	105,529	2,497	23.7	
1913	111,788	2,417	21.6	
1914	118,046	2,631	22.3	
1915	124,304	2,681	21.6	
1916	130,563	2,628	20.1	
1917	136,821	2,875	21.0	
1918	143,080	3,674	25.7	
1919	149,338	3,203	21.4	
1920	161,015	3,214	20.0	29.2
1921	178,112	2,901	16.3	32.0
1922	195,208	3,143	16.3	33.2
1923	212,305	3,408	16.1	34.5
1924	229,401	3,649	15.9	32.9
1925	246,498	4,093	16.6	**
1926	263,594	4,415	16.7	33.7
1927	280,691	4,372	15.6	34.8
1928	297,787	5,221	17.5	34.4
1929	314,884	4,926	15.6	35.8
1930	330,932	5,265	15.9	36.3
1931	343,833	5,583	16.2	36.9
1932	356,735	5,293	14.8	38.5
1933	369,637	5,517	14.9	39.0
1934	382,539	5,548	14.5	41.1
1935	395,441	5,760	14.6	40.7
1936	408,343	6,092	14.9	41.3
1937	421,245	5,969	14.2	42.4
1938	434,147	5,554	12.8	43.6
1939	447,049	5,632	12.6	43.8
1940	459,951	5,616	12.2	45.6

Source: Bureau of Vital Records and Statistics, Department of Health, City of New York

* Rate per 1,000 population

** Not available

amount of disability per person due to illness which incapacited for a week or longer was 43 per cent higher in the Negro than in the white population; that the higher disability rate for Negroes was due chiefly to the chronic diseases; and that the average Negro in the nonrelief class experienced only one-half as much disability per year (in a twelve month survey made during 1935-1936) as the average Negro on relief. I quote from Holland and Perrott:

> "Low economic status, rather than inherent racial characteristics in the reaction to disease, thus appears to account in large measure for the higher disability rate observed among Negroes. From this fact it follows that the health problems of Negroes are more serious than those of the average white population since they represent in the mass a low-income group, unleavened, as in the white population, by any considerable number in the higher income range."

SYPHILIS

Recent surveys stimulated by the war effort have furnished a clue to the prevalence of this preventable illness. Results of serological tests performed on 1,895,788 selectees and volunteers (Vonderlehr and Usilton '42) yielded the folowing estimated rates of syphilis prevalence: for the entire male population of the United States between the ages of 21 and 35, 47.7 per thousand; for Negroes, 272, and for whites, 23.5 per thousand; for the rural population, 49.4, and for the urban, 46.5 per thousand. The highest syphilis prevalence rates are encountered in the Southeastern states.

I quote from a subsequent publication by Vonderlehr and Usilton ('43):

> "Syphilis shortens life expectancy between the ages of 30 and 60 by 17 to 30 per cent.
>
> "In the five-year period from 1936 to 1941 the chance of acquiring syphilis has registered a significant drop.
>
> "A new rate of prevalence was calculated. We shall take 'rate of prevalence' to mean that fraction of any population group alive at any given time who have syphilis detectable by the serological blood test."

The results shown in Table 2 were obtained by Vonderlehr and Usilton by using the calculated prevalence rate as the rate which would prevail if all syphilis up to 1936 had been acquired at the 1936-1937 attack rates and from 1936 to 1940 at the mean of the 1936-1937 and the 1940-1941 attack rates.

TABLE 2

Calculated syphilis prevalence rate per 1000

AGE GROUP	WHITE MALES	COLORED MALES
21-25	13.8	179.1
26-30	32.6	326.8
31-35	53.0	431.0

Gill *et al.* ('43) found that in Alabama 19.8 per cent of the colored and 1.5 per cent of the white registrants had positive tests for syphilis.[7] There is a higher syphilis attack in Negroes than whites anywhere in one and the same area which can be explained by the Negroes' lower status of health education and general indolence in regard to venereal disease control in the past era.

The present appraisal of the syphilis situation is that for the entire country the problem is about ten times greater for Negroes than for whites.

From the geographical point of view the prevalence is greater in areas with a high proportion of Negro population; and in those localities where the Negroes have an especially high percentage of syphilis, its prevalence is, as a rule, in whites also above the average national prevalence for whites. Though that tendency is consistent, this relationship, however, is not a constant proportion (Vonderlehr and Usilton '42). Nevertheless, certain regional environmental conditions in which both races share, are suggested by the concomitant high rates where they prevail.

At this point it may be appropriate to mention a new sociological phenomenon which can be attributed to the effects of the war. Public health workers dealing with the control of venereal diseases observed that while professional prostitution did not exist to any noticeable degree, if at all, among Negroes in the South, monetary renumeration for sexual services is becoming a frequent practice at present.[8] While it

[7] It must be noted that estimated rates based on correction for age would yield higher values for that state.

[8] Prostitution must be sharply differentiated from non-marital relations leading to a high proportion of illegitimacy among the Negroes. Before the outbreak of the war, the illegitimacy rate for the colored population in Jefferson County, Alabama, was sixteen times higher than for the white population, namely, 16.7 per 1000 families (Housing Authority of the Birmingham District '43).

would not be prudent to cite herein the percentage of infections detected in Negro soldiers and classified as paid exposures, it may be stated that the figure is not negligible in one of the Southern states. At the same time it is interesting to note that thus far no procurers in the sense of professional facilitaters were used by those Negroes.

These observations on behaviorism are included in my study because they present a facet presumably not encountered until very recently, as far as the Negro is concerned. Moreover, during the post-war reconstruction period the interrelation between health and mores, the problems of social adjustment and leisure time activities, will require ever-increasing attention.

TUBERCULOSIS

The relative frequency of disseminated forms of tuberculosis is considerably higher in Negroes than in whites and the decrease of disseminated forms during the last 17 years is much smaller in Negroes than in whites (Pinner '40). In 1942 the tuberculosis mortality rate for Negroes was more than three and one-half times larger than for whites (Metropolitan Life Insurance Company '43). From this it follows that especially vigorous steps must be undertaken to conquer that plague in all areas where the Negro constitutes a large proportion of the general population. This applies specifically to the Southern states, irrespective of the fact that due to some still unknown reasons the tuberculosis rate for Negroes is higher in Northern and Western cities than in Southern cities, in analogy to a higher rate in the Northern and Western cities among whites (National Tuberculosis Association '41).

Tuberculosis death rates are considerably higher in urban than rural communities, and it is noteworthy that the rate declined from 42.2 to 41.7 per 100,000 from 1940 to 1941 in 18 large cities among whites, while it rose among Negroes in the same localities during the same time from 199.1 to 203.3 (National Tuberculosis Association '41).

My discussion of the availability of tuberculosis control measures concerning the Negro needs a few introductory remarks. It has been estimated that in the population as a whole there are ten active cases of tuberculosis for each death and that a minimum of two hospital beds for each annual death is needed where a good case-finding program is carried on and well-equipped institutions are available (Chadwick '40).

What is the relation between existing needs and available facilities? Hospital provisions for Negroes vary greatly from state to state. For example, for tuberculous colored patients there were 699 hospital beds in North Carolina and 187 in Alabama, in 1942. In North Carolina there were (in 1940) 1783 deaths from tuberculosis in the entire population and a ratio of 1.5 hospital beds for tuberculous patients per death; in Alabama 1499 deaths from tuberculosis (in 1940, also in both races) and a ratio of 0.3 hospital beds (National Tuberculosis Association '42). Ratios as low as these are not only too low for the respective populations as a whole (by way of illustration I restricted myself to figures for two states), but they indicate a special scantity in hospital facilities for tuberculous Negroes in view of the high incidence of tuberculosis in that race and also the large proportion of the Negro population in the South.

The South, which has the smallest per capita income, provides fewest beds per unit of population (Mountin *et al.* '39). The greater failure in the South than in the North, to reach the minimum standard of two beds needed per annual death from tuberculosis is also apparent from the study of Dempsey ('43).

At present there are no data allowing a conclusive comparison between public health measures apportioned to Negroes and whites. Federal grants to State Health Departments do not specify to what extent each race is to be aided by such assistance.

A study of State Health Departments undertaken by the U. S. Public Health Service revealed, among other things, that the per capita expenditure among individual states ranged from $1.68 to 13.4 cents and that Federal grants represented about "one third of the total amount expended" (The Military Surgeon '43).

A comparison of some health services available to Negroes and whites, specifically, in 96 Southern counties, during 1930 to 1939, has been carried out by Cornely ('42). It was noted that most of the health units did not tabulate their essential data according to color, but certain trends could be observed. I quote from Cornely's investigation which included 12 states with only 3 of the Southern states (Texas, Arkansas and West Virginia) not participating in the survey and Alabama having the largest representation of counties in the study:

> "Although tuberculosis is the foremost plague of the Negro, yet in this group of counties, he has available less clinic service and fewer beds per death (than whites).

> "In the venereal disease field the Negro fares better—most likely as the result of the recent crusade—since he has twice as many clinic hours allocated to him per week as do his white brethren; but even this is not in proportion to the disparity existing between the incidence in the two races. The same outlook is to be found in the maternal and child health sphere. This study showed alarming neglect in the health supervision of Negro school children. In 1939, eleven of the 58 counties reported no examination of Negro school children, while only one reported this deficiency for white school children."

Cornely's entire analysis brought out that there is "a dire urgency for the development of a comprehensive approach to the manifold health problems of the Negro."

PUBLIC ASSISTANCE

It is impossible to appraise to what extent improvements in the mode of life of the Negro were enhanced by all kinds of philanthropy.

In a letter addressed to the author on July 8th, 1941, Mr. Henry J. Rosner, Assistant to the Commissioner of Welfare of New York, draws attention to the fact that relief to veterans and their families was first established in 1886 and was originally given through veteran organizations. "Recently," writes Mr. Rosner, "veteran relief has been given through the Department of Welfare, and is, in fact, an integral part of Home Relief.

> "Public assistance given outside of institutions were Widow's Pension, now known as Aid to Dependent Children given through the Board of Child Welfare and established in 1915.
>
> "Home Relief was first given to the unemployed in December 1931.
>
> "While the Department of Welfare does not maintain statistical information concerning the number of Negroes receiving Home Relief, we have made several estimates since 1936. At the end of June, 1936, it was estimated that there were approximately 42,250 Negro cases on the Home Relief rolls, with approximately 105,600 persons. In March, 1939, it was estimated that there were approximately 43,600 such cases, with approximately 110,550 persons. An estimate of the number of Negroes on Home Relief in Harlem as of mid-May, 1941, indicated a total of 26,250 such cases with approximately 62,800 persons.
>
> "Today, it must be remembered that WPA is also aiding Negroes through public funds for work projects."

It would be beyond the scope of the present study to compare the public relief funds spent in different localities. As already pointed out,

the size of the problem is greater in the South than the North, and with a higher percentage of Negro population the amounts needed for all health and welfare services are larger in the South.

For 34 urban areas with a population of 17,243,294 (whites and Negroes combined) public responsibilities which were met in 1940 by Federal sources amounted to 45.7 per cent of the funds derived from all sources, and 37.5 per cent were supplied by the Government for wage programs such as WPA, CCC and NYA (U. S. Department of Labor '41). With the discontinuation in 1943 of such Federal projects, relief problems will have to be met to a greater extent by local and state funds if possible. A single example suffices to illustrate the issue. In 1940 Federal funds contributed to the public needs of Jefferson County, Alabama, 73.4 per cent out of all available resources (Birmingham Housing Authority '43) as against 45.7 per cent for 34 urban areas as mentioned above. In that particular Southern area the bulk of Federal assistance was in the form of wage programs. While some of the individuals formerly employed by the WPA can find adequate positions with a sufficient amount of earning, others will need support by welfare agencies.

At the time of this writing expenditures for public assistance cannot be conclusively used to determine the quantity nor the quality of environmental improvements as they pertain to the Negro. There are no data available in order to establish to what degree the Negro population has benefited by a wage program as gigantic in scope as the WPA because this as well as other projects sponsored by the Government show total expenditures without giving separate figures for whites and Negroes.

In the face of this handicap I did not include in my study of environmental trends, details as to housing. However, the following remarks seem to be pertinent. In the experience of many observers there exists a high proportion of problem families in areas with substandard housing; and, as a rule, populations living in such districts must receive substantial financial assistance, a large amount of health service, much attention as to social adjustment, and it is particularly in these underprivileged groups where leisure time service is being rendered in inverse proportion to the actual needs. All this applies especially to the Negro (Birmingham Housing Authority '43), and the situation is more acute in the South than the North.

A correlation between improved housing and physical growth of the Negro will become possible in those sections of the country where slums have been converted into up-to-date neighborhoods, provided a given population remains in one and the same environment long enough in order to enable a protracted follow-up. In this connection the following observation is of interest: I found that in Smithfield Court, Birmingham, Alabama, which is an all-Negro housing project[9] containing over 500 units, an average of 17.8 per cent of dwellers left annually (calculated for the period from July 1, 1939 to June 30, 1941). However, it was mainly the unattached person who left while families showed a definite tendency to remain stationary in the new environment whose characteristics are: low rent, wholesome quarters, spacious playing grounds and an atmosphere of respectability. Settlements of this kind, all of very recent origin, display a certain socio-economic homogeneity and typify a new environmental trend among the Negroes of the South. First, personal and financial qualifications (the latter being more modest and flexible than in analogous housing projects for whites) which must be met prior to admission to such a community, enable only a definite class of people to join the latter; second, in view of traditional racial restrictions in the South, no better housing accommodations are accessible to the Negro regardless of financial resources. Thus, while living in a housing project signifies for the white his belonging to a limited wage bracket, it means something entirely different to the Southern Negro; namely, his inclusion in a selected group carries a definite prestige. There is an outspoken sense of civic pride and personal self-respect among the inhabitants of a southern Negro housing project.

It remains to be seen to what degree the new southern Negro neighborhoods characterized by those locally determined marks of distinction[10] will influence the physical development of the generation growing up there.

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[9] Created by the U. S. Housing Authority and promoted by local Housing Authorities, durable dwellings were set up to liquidate themselves financially in 60 years and then to become the property of the respective cities.

[10] The qualitative appraisal of the role of a southern all-Negro housing project is included herein because it demonstrates the relativity of values in regard to behavioristic attitudes.

THE PROLONGATION OF THE LIFE SPAN FOR WHITES AND NEGROES IN A NORTHERN AND A SOUTHERN CITY

How does the progress in environmental improvement for whites and for Negroes compare? We do not have any exact knowledge in order to answer this question. If we were able to draw comparable graphs, we might possibly come to the conclusion that the Negroes' upward curve begins its ascent from a level lower that that of the whites and falls short of the summit which the corresponding line of the whites has already reached.

I have used the prolongation in the life span as a hypothetical index to evaluate the totality of environmental improvements; specifically, I have utilized the increase in the mean age at death[11] in order to indicate the existence of such improvements; and I know that in doing so, my procedure as well as its results may be challenged.

In principle, the following objections may be voiced. I quote from *Vital Statistics* by Newsholme ('24):

> "In contrasting different communities the mean age at death is a most fallacious test, owing to variations in the birthrate and in migration of population.
>
> "In the comparison of different classes of society, and those engaged in different occupations, serious errors have arisen by the use of the mean age at death to determine their relative vitality."

I do share these objections. However, the totality of environmental conditions includes the variations in birth-rate and in migration of population, occupational health hazards to which are exposed certain age groups engaged in the respective occupations, social-economic fluctuations in given territories, nutritional opportunities or a lack of them in accordance with the state of wealth or poverty, and the effects of public welfare and public health.

It was not my aim to utilize the mean age at death to contrast different communities nor to determine the relative vitality of the Negro and white populations. Something else was intended, namely, in considering the average age at death as the sum total of numerous environmental factors, I could not ignore the increase in the average

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[11] Mean age at death $= \frac{\text{sum of ages at death}}{\text{number of deaths}}$.
This corresponds to expectation of life at birth.

age at death, as a general indicator of environmental changes, including improvements.

Environmental conditions have also an effect on the proportion of the age groups in a population and that proportion will affect the total death rate as well as the mean age at death.[12]

I cannot itemize the very many factors which have engendered an improvement in the Negro's longevity. The answer would have to be looked for in an all-inclusive historical survey on public health activities and socio-economic adjustments, including their limitations; and the results of private philanthropy as well as of public welfare would have to be weighed, too. Various sciences would have to be intergrated in order to approach a project of such magnitude adequately.

To what degree will general environmental changes exert their beneficial influence on the white and Negro populations in one and the same territory?

I may cite some figures for Birmingham, Alabama, and New York City, New York, analyzing separately data for the Southern coal, steel and iron center and for the North-eastern metropolis in Table 3.

Table 3 demonstrates that during the decade 1930 to 1940 the average age at death has increased equally for whites and Negroes of the Birmingham population, the extension of the life span in both races being 5.7 years.

In 1930 the average life span of the colored population of Birmingham was by 9.2 years shorter than that of whites, and in 1940 the same difference prevailed.

During the same decade the average age at death has increased about equally for whites and Negroes of the New York City population, the

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[12] The rates for infant and maternal mortality show marked differences for different localities. Comparison of the infant mortality rate for 1931-1935 with that for 1936-1940 reveals a percentage decrease of 21.0 for New York and 2.2 for Alabama; and comparison of the maternal mortality rate for the same period shows a percentage decrease of 34.2 for New York and 9.2 for Alabama. In Negroes the general improvement in maternal mortality was less than in whites: from 1930 to 1940 the maternal mortality rate became 48 per cent lower in whites and 34 per cent lower in Negroes (Yerushalmy '42).

The increase of the old age group, i. e. the population 65 years old or over, during the preceding decade shows also different trends in different localities. The increase for that group in the country as a whole was 35 per cent; however, in New York City the increase was 57 per cent comprising 5.6 per cent of its total population in 1940 (Welfare Council New York City '43).

TABLE 3

Average age at death (in years)

	WHITE	NEGRO	DIFFERENCE BETWEEN WHITE AND NEGRO IN LIFE SPAN
	*Birmingham, Alabama**		
1930	45.3	36.1	9.2
1940	51.0	41.8	9.2
Increase in one decade	5.7	5.7	
	*New York City, New York***		
1930	49.0	36.3	12.7
1940	58.0	45.6	12.4
Increase in one decade	9.0	9.3	

* Jefferson County Board of Health, Birmingham, Alabama, '40.
** Dept. of Health, New York City. Personal communication.

extension of the life span for whites being 9 years and for Negroes 9.3 years.

In 1930 the average life span of the colored population of New York City was by 12.7 years shorter than that of whites in the same city; and in 1940 about the same difference prevailed.

Of course, none of the figures for these two cities are comparable. Moreover, though each city, taken separately, discloses one and the same phenomenon, namely, a parallel extension of the life span for whites and Negroes in one and the same locality, the analogy of the figures is deceiving, deceiving because in terms of percentages the prolongation of the life span is greater for Negroes than whites.

From this fact one may deduce that during the last decade the totality of environmental changes, including improvements, occurred in no lesser degree among Negroes than whites.

SUMMARY AND CONCLUSIONS

The nutritional regime applied to infants under care of the Department of Health of New York City is reported. This dietary and general supervision introduced about one decade ago in behalf of indigent in-

fants, both white and colored, has benefited their growth as shown in previous papers of the present series.

Manifold improvements can be recorded in the Negro's general health during the past quarter of the present century. However, the Negro's greater illness than that of the white is striking. This can be linked with the former's poorer economic status.

Health facilities available to the Negro are not on a par with those available to the white, for the country as a whole. Especially inadequate are facilities for tuberculosis control. This applies also to venereal disease control, though to a lesser degree, due to the program accompanying the war effort.

To a great extent progress in the Negro's living conditions was enhanced through the aid of public agencies.

It seems that during the last decade the effects of the totality of environmental changes, including improvements, were sufficiently potent among whites and Negroes as to cause an upward extension of the average life span in both races.

The use of the life span as a criterion for environmental changes is only permissible when heeding the necessary reservations.

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STUDIES IN THE PHYSICAL DEVELOPMENT

VIII. RÉSUMÉ AND GOALS FOR FURTHER RESEARCH

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INTRODUCTION

IN THE present paper the period of gestation, the tempo of growth, and the desirability of obtaining consecutive observations in order to investigate those factors which may possibly influence the individual's natural life span are discussed.

In appraising the life cycle as a whole, reference is made to some aspects of heredity and environment.

THE PERIOD OF GESTATION

Anderson, Brown and Lyon ('43) drew attention to that which seems to be a difference between gestation periods of white and Negro infants, as shown in Table 1.

TABLE 1

*Mean gestation period, mode and standard deviation for white and Negro single live-born infants**

RACE	NUMBER	MEAN (in days)	MODE (in days)	STANDARD DEVIATION (in days)	(in years)
White	2948	279.4	283.6	20.6	.06
Negro	1895	274.0	277.0	21.1	.06

* Calculation based on the frequency distribution contained in Table 3 of Anderson *et al.* ('43)

It would be of interest to determine whether or to what degree there can be demonstrated a shorter gestation period of Negroes than whites among infants of multiple birth order and excluding premature infants.

Duffield, Parker and Baumgarten ('40) have shown that there is a very much larger percentage of infants with birth weight less than 2500 grams among the plural-born than single-born infants in whites as well as Negroes. From this it follows that prematurity is relatively more frequent in plural-born than single-born infants. However, the incidence of prematurity appraised from the point of view of birth weight cannot be evaluated in the same manner for whites and Negroes due to the lower birth weight of the latter. Anderson *et al.* ('43) suggested separate birth weight standards for the white and Negro races: 2500 grams to be considered the lower limit of normal for the white infant and 2300 grams as the lower limit of normal for the Negro infant.

Anderson *et al.* ('43) obtained for 1144 single-born Negro males a mean birth weight of 3154 grams ± 541; and for 1153 single-born Negro females 3053 grams ± 539. These means resemble those reported for Negroes by the author ('43) and are for each sex smaller by about 100 grams than the latter's figures which, however, were calculated without considering birth order. In the material of Anderson *et al.* the variability of the birth weights of whites and Negroes was practically the same for the comparable Cincinnati populations (irrespective of the higher means for whites in the corresponding sex), and the frequency distribution by gestation period presented by Anderson *et al.* and used herein embraces data with known last menstrual period. These aspects enhance a high degree of reliability as regards the material of Anderson *et al.*

With a normal variability of about ± 21 days for the gestation period, there arises the question whether there is a correlation, in the sense of a causative relationship, between the normal length of time spent *in utero* and the individual's natural life span; and, furthermore, whether the shorter gestation period of the Negro (provided it be not merely a statistical phenomenon) has any influence on the shorter life span of Negroes than whites. At present no data are available to attempt a probing into these purely hypothetical questions.

Similarly, we lack any consecutive observations in order to clarify the problem whether the individual's tempo of growth as affected by genetic or environmental factors, exerts an influence on his duration of life. Of special value would be an answer to the problem whether the tempo of growth due to hereditary determinants has a bearing on the length of the natural life span.

ENVIRONMENT AND PHYSICAL DIVERGENCES

Burke, Harding and Stuart ('43) have shown that the amount of protein contained in the prenatal diet may influence the size of the infant. Less than 75 grams of protein daily during the latter part of pregnancy was found to result in infants of light weight and short stature while both of these measurements reached higher figures, irrespective of the mother's height, when the prenatal diet was well supplied with protein.

Burke, Beal, Kirkwood and Stuart ('43) have also shown that the mode of nutrition during pregnancy may profoundly affect the condition of the infant at birth. I quote:

> "A statistically significant relationship has been shown between the diet of the mother during pregnancy and the condition of her infant at birth and within the first two weeks of life.
>
> "If the diet of the mother during pregnancy is poor, she will undoubtedly have an infant whose physical condition will be poor. In the 216 cases considered in this study, all stillborn infants, all infants who died within a few days of birth except one, most infants who had marked congenital defects, all premature, and all functionally immature infants were born to mothers whose diets during pregnancy were very inadequate.
>
> "If the mother's diet during pregnancy is good or excellent, her infant will in all probability be in good or excellent physical condition. It may, however, happen rarely that a mother whose diet during pregnancy is good or excellent will give birth to an infant in poor physical condition (1 out of 216 cases in this study)."

A recent study carried out on a series of Negro infants by Bakwin and Patrick ('44) merits special attention. That Negro group is unique in that it is made up of private patients in contrast to dispensary material observed previously. The infants of the new series were supervised by Patrick since their birth. Bakwin and Patrick have compared the weight curves of those private colored patients with the data obtained from a group of white infants supervised at the Fifth Avenue Hospital (Bakwin and Bakwin ('36). Bakwin and Patrick conclude:

> "There is no significant difference in the weight gain of white and Negro infants during the first year of life. It seems likely that the slower growth observed in earlier studies was due to differences in socio-economic status rather than to differences in the nature of the germ plasm. Given the opportunity of proper medical supervision, Negro infants from moderate income families grow as well as white infants."

A particularly timely issue is the eugenic question dealing with genetic versus environmental disturbances. Hale's ('35) experiments as well as those by Warkany *et al.* ('43) demonstrate that unfavorable prenatal nutrition can cause familial, though not hereditary, congenital malformations. I quote from Warkany *et al.*:

> "Studies in human twins and in strains of mice with a hereditary tendency to harelip and cleft palate have led to the conclusion that non-genetic factors modify the manifestations of the pathological tendency to a great extent.
>
> "Harelip (studied by Hale) and cleft palate have been produced by maternal nutritional deficiency in strains of animals which were free of these malformations under adequate nutritional conditions.
>
> "There seems to be no reliable method available at the present time to ascertain in a given case whether the anomaly is due to genetic or to environmental disturbance."

In a discussion of environmental factors one might cite the hypothetical role of climate which in the opinion of some authors has a decisive effect on birth weight, the onset of sexual maturity, and height. However no consistent nor significant seasonal variation in birth weight could be demonstrated in a recent study by Meredith and Brown ('39). Similarly, Gadgieva ('41) established for about 31,000 children born in Baku from 1930 to 1936 inclusive, the lack of any dependence of the birth weight on the season of the year.

From the author's study (Michelson '44) one may deduce that the time at onset of puberty is not influenced by climate. As far as stature is concerned, one may point out that no stifling effect due to a warmer climate could be observed in New York among American-born offspring of groups of East European Jews who have come to this country from colder climates; on the contrary, an increase in stature could be shown. Moreover, if climate were a potent factor and a colder climate had the specific effect leading to an increase in adult stature, one would expect such a result among Negroes growing up in New York. However, no recent secular increase in adult stature could be demonstrated for them.

The notion that a hot climate must result in small stature and a cold climate in tall stature is also contradicted by the well known fact that some of the tallest men are found among the Soudan Negroes and that the average height of the Scandinavian Lapps is about only sixty inches. Thus it seems that the effect of climate on physical development is a highly contestable idea.

Shapiro ('39) has demonstrated that selection may constitute an important issue when comparing emigrants with the general population from which they are derived. Equally significant is the following con-

TABLE 2

Average statures and annual increment (in cm.) of girls between 11 and 13 years of age among various populations

White

	BRUSH FOUNDATION REGULAR SERIES SIMMONS AND GREULICH ('43)		CALIFORNIA GENERAL POPULATION U. S. DEPT OF AGRIC. ('41)		UNIV. OF IOWA STUDIES BOYNTON ('36)		TENNESSEE GENERAL POPULATION U. S. DEPT OF AGRIC. ('41)	
Age	Stature	Increment	Stature	Increment	Stature	Increment	Stature	Increment
11	148.57		146.85	.	143.62	.	142.09	.
12	155.16	6.59	152.29	5.44	150.28	6.66	148.62	6.53
13	160.03	4.87	156.48	4.19	155.96	5.68	153.87	5.25
11-13		11.46		9.63		12.34		11.78

Negro

	RIVERDALE ORPHANAGE NEW YORK MICHELSON ('44)		P. S. 136, NEW YORK CITY MICHELSON ('44)	
Age	Stature	Increment	Stature	Increment
11	137.4		146.4	
12	143.3	5.9	152.1	6.3
13	148.7	5.4	154.9	2.8
11-13		11.3		9.1

clusion of Shapiro: "Not only may migrant populations undergo modification when transposed to a sufficiently different environment, but physical changes may also occur in fixed populations if their environments alter in the course of time."

The average speed with which premenarcheal growth in stature manfests itself in different populations merits a detailed discussion.

A comparison of six different populations for which data are presented in Tables 2 and 3 reveals:

First, there occurs a greater spurt in stature between 11 and 12 years of age than between 12 and 13 years. From 12 to 13 years of age growth in height is already decelerating.

Second, for the two follow-up series for which the age of menarche is known (Brush Foundation Regular Series, white well-to-do girls:

TABLE 3

Increment between 11 and 13 years of age expressed as percentage of stature at 11 years

Brush Foundation (families above the average in economic status)	7.67%
California	6.56%
Iowa (above average in economic status)	8.59%
Tennessee	8.29%
Riverdale Orphanage	8.22%
P. S. 136	6.22%

12.6 years ± 1.1; and Negro orphanage girls: 13.5 ± 1.1) one notices that (a) although the Brush Foundation Regular Series has the menarche one year earlier than the Negroes of the Riverdale Orphanage, the difference in the intensity of the increment does not appear to be significant as regards the time interval between 11 and 13 years of age; (b) both groups differ by eleven centimeters at 11 years of age and still differ by the same amount at 13 years of age; and (c) both groups show an increment of approximately 8 per cent in relation to the stature at 11 years of age.

Third, in all six populations compared, even though they differ markedly from the standpoint of economic status and race (color), still their increments in stature between 11 and 12 years of age are similar. The increment for the interval between 11 and 13 years of age, expressed as percentage of stature at 11 years, ranges from 6.2 per cent to 8.6 per cent.

In terms of the problem of the relation between sexual maturation and increment in stature, the above data would indicate that the increment in height is more definitely related to age than to the onset of puberty or socio-economic status, in so far as this applies to a large population. It should be realized, however, that this general conclusion does not apply to selected groups nor to each individual contained in a group.

For example, a series of girls representing a well-to-do group is expected to contain a relatively large proportion of individuals with accelerated growth in stature and an acceleration of the onset of puberty; and such a group may show a more intensive premenarcheal spurt in stature between 10 and 11 years than later on. This did actually occur in the Brush Foundation Regular Series.

Individual divergences due to an interrelation between the onset of puberty and the tempo of growth in stature show in most cases these characteristics: girls with an early menarche have the greatest acceleration followed by the greatest deceleration; girls with a late menarche experience the least acceleration followed by the least deceleration (Simmons and Greulich, '43). Or, in other words, the intensity of growth during the period of growth is the less the later adolescence sets in. (Boas '32)

Assuming that nutrition is one of the factors forming a part of environmental changes and influencing the tempo of growth, and assuming also that nutrition influences mature physique, are we dealing with a single nutritional factor, namely, (a) a factor which leads to accelerated growth; or with an additional nutritional factor, namely, (b) a factor that effects a secular increase in adult stature?

If in one given locality there should occur (1) an accelerated tempo of growth; (2) accelerated onset of puberty; (3) an increase in the linear type, that is to say, a growing proportion of individuals with slender build; and (4) an increase in adult stature, one may be tempted to ascribe the concurrence of all of these physical changes to one single hypothetical cause. For example, one may raise the question whether there is occurring a possible increase of iodine entering the food, as it is believed by some investigators that thyroid stimulation may affect the individual in this manner. However, thus far, there is neither evidence of a consistent concurrence of those four phenomena in all population groups of the same locality, nor has a greater consumption of iodine (in terms of food) during the past decades or centuries been demonstrated.

It seems that an explanation for secular bodily changes is not to be sought for in any single cause but in a combination of several concurrent or interacting factors—all unknown at present and probably including variables not sufficiently appraised.

THE TEMPO OF GROWTH AND OF SENILE DECAY

Sherman and Campbell ('37) demonstrated that rats whose basal ration was fortified with skim milk powder grew very much faster than a control series not receiving the supplemented diet. The supplemented animals showed an earlier sexual maturation, a grater duration of the reproduction period and a longer life span. As far as humans are concerned, there do not exist any data disclosing a similar correlation between environmentally caused growth acceleration and prolongation of longevity.

The proof that longevity of the parents influences that of their children was established by the study of Bell ('18) whose analysis of the genealogy of the Hyde family showed that four times as many individuals attained old age when both parents lived 80 years or more than when neither parent reached that age. Among other things, he also found that the first-born lived as long as subsequent children. However, the latter observation does not agree with the results obtained by Beeton and Pearson ('01) who found that older children had longer lives than the younger ones of the same family:

> "The elder adult sister and adult brother live on an average four years longer than the younger adult sister or brother."

No attempt is being made herein to explain the different results on this issue as obtained in Bell's investigation and in that of Beeton and Pearson. It is clear, however, that in addition to statistical investigations of the duration of lives, studies are needed in order to identify the type and developmental tempo of separate physiological events possibly bound up with hereditary determinants of longevity. This might clarify the role of the tempo of growth as well as the role of the tempo of aging in relation to longevity.

Let us review a few relevant observations on the tempo of growth as brought out in the present study in order to discuss the problem of the tempo of growth in relation to the life span, later on.

I wish to refer back to the basic concept of physical growth (as expressed by stature) which was already formulated. One must strive to identify the factors which influence the individual's tempo of growth and to distinguish them from those which are instrumental in causing a change in the adult stature of successive generations. The rhythm of growth is determined by a combination of two elements, namely, the effects of heredity and of environment. Adult stature does not seem to be influenc-

ed by acceleration or retardation of growth occurring within the same social group (Boas '32). The increase in the adult stature of whites which has been noted by many investigators must be considered a non-hereditary, physiologic manifestation brought about by long-lasting environmental improvements. In view of the fact that no increase in the final stature of the Negro could be demonstrated in the present investigation (Michelson '43), we may conclude that the environmental conditions under which this race grew up during the last few decades, have not as yet improved to a degree (either quantitatively or qualitatively) which could bring about an increase in the adult stature.

The following also bears repetition: Although it has been shown (Michelson '43) that Negro infants and children supervised by the Clinics of the Health Department of New York City have made an astounding recent increase in stature and that this may possibly be attributed to the effects of environmental improvements (presumably the increase is due to acceleration in growth), only a follow-up of these Negro children until the termination of their growth cycle would disclose whether the adult stature will excel that of previous generations.

It was brought out (Michelson '44) that among both white and colored girls of the present generation puberty sets in at an earlier age than it did during preceding decades. However, it must be underscored that the cause of the concurrence of accelerated growth and accelerated sexual maturity is not as yet understood.

The relation of both of these phenomena to longevity ought to be a subject matter of research.

So far, we lack any knowledge about a relationship between the individual's tempo of growth and longevity. An investigation of this problem would have to deal with two questions: first, the correlation between a hereditary tempo of growth and the natural life span; and, secondly, a correlation between environmental effects on the rate of growth and a possible modification by such extrinsic factors of the natural life span.

In order to come nearer to an answer to these problems, a separation between hereditary and environmental factors, in so far as they form independent components of the growth cycle, would be the first step. Obviously, their recognition and formulation in quantitative terms is very difficult (see Boas, '32, pp. 345-349).

In this connection, it is important to keep in mind that the correlation coefficient for the resemblance of fraternities is merely an expression for the dissimilarity of the family lines and does not possess any biological

significance. In a population in which the variability of the fraternities is very much greater than that of the families, there is much inbreeding (Boas '31).

Since the growth cycle as expressed by stature is only one of the many biologic phenomena which might possibly be linked with longevity, a differential analysis of intrinsic (hereditary) and extrinsic (environmental) factors would have to be made for all physiologic manifestations expressing the tempo of physical development as well as that of senile decay.

The premise to an enquiry of such a large scope is an organization of continuous observations to be carried out from birth to death of the populations under study.

The problem of a possible relationship between the tempo of growth and longevity culminates in the question "whether the characteristic tempo of the individual extends over later periods of life; whether a rapid tempo of growth will also be associated with rapid decay and earlier death, or whether other types of relation exist" (Boas '35).

We do not know whether acceleration or retardation in physical development which takes place during an individual's earlier part of life is followed by a similar tempo of physiological changes throughout life. If it could be determined whether the tempo of development and that of senile decay fall into one and the same pattern during the entire life of the individual and if such a supposition could be shown to be true, the individual's natural life span might become predictable. At present we have no data which might prove the existence of a correlation between, let us assume, a slow tempo of development and a slow tempo of aging. However, the following is suggestive: in the sequence of events which occur during the processes of growth and senile decline one can note that the later the chronological order of appearance of a physiologic stage is, the greater is its variability (Boas '40, pp. 98 and 112) in terms of years.

The demonstration by Bernstein ('31, '32) and Steinhaus ('32) that those individuals who become far-sighted prematurely are apt to succumb to arteriosclerotic changes of old age earlier than those who become far-sighted late in life, merits special attention because this observation would permit some kind of prediction of an individual's probable natural life span.

It is interesting to note that the individual's life span has shown only a minimal change for the age group seventy years and over, since 1876 to

1937 (Wolff '43), the increase amounting only to 0.4 years for the male and 0.8 years for the female.

The fact that there is a progressive increase in variability for the time of onset of the consecutive physiologic events, starting with ± 21 days for the gestation period and ending with ± 8 years for death from arterial diseases; and also the fact that there appears to be a prolongation in the life span amounting for the older age groups to a few months during the last six decades of observation—these two circumstances give rise to the following questions: (a) Has a speeding up of physical growth caused by environment (for example, accelerated sexual maturity) any subsequent effect on longevity? (b) Are the hereditary factors potent to such a degree that the natural life span will not be prolonged beyond the average already attained by the human species, irrespective of environmental improvements?

I may briefly refer to another subject of great interest, namely, the relation between skeletal and mental development. It would be enlightening to investigate whether there exists a relation between the tempo of skeletal development and the intelligence quotient of the Negro. Boas ('41) reported a correlation between the stature of white children and the tempo of ossification of the radius. A correlation was also found between the rate of development of the radius and the intelligence quotient. Children short for their age had a low I. Q. and a slow tempo of ossification of the radius. Such correlations could not be studied for adults due to lack of follow-up material; and for Negroes a similar study could not be undertaken at all, for the same reason.

In so far as non-adults are concerned, a concurrence of a relatively high stature, an advanced stage of ossification of the radius and a high I.Q. may be explained by an acceleration of physical as well as mental development. Since the final stature does not depend on acceleration nor retardation of growth, it would be logical not to expect a correlation between the adult stature and the I.Q.

SUMMARY

This study presents an interpretive résumé on growth as well as on questions pertaining to heredity and environment, whereby the discussion is chiefly focused on problems considered in the previous papers of the present series. In addition, some other aspects, in need of further research, are touched on.

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